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VIBRATION CHARACTERIZATION AND HEALTH RISK ASSESSMENT OF THE VERMONT ARMY NATIONAL GUARD UH-72 LAKOTA AND HH-60M MEDEVAC

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14. ABSTRACT This study characterized and assessed aircrew vibration during operation of the UH-72 Lakota and HH-60M Medevac located at the Vermont Army National Guard. The ISO 2631-1: 1997 was used as the guideline for the assessments. Triaxial accelerations were collected at the floor/seat base, seat pan, and seat back interfaces at the pilot, crew chief, and medic stations. Data records were collected by aircraft task and flight test conditions. All stations aboard the UH-72 showed a major spectral peak in all three directions between 24 and 25 Hz. All stations aboard the HH-60M showed a major peak in all three directions between 17-17.5 Hz. These peaks were associated with the blade passage frequency of the respective aircraft. Based on the overall vibration total value (ISO 2631-1), comfort reactions for the UH-72 primarily ranged from "not uncomfortable" to "fairly uncomfortable". Comfort reactions for the HH-60M primarily ranged from "a little uncomfortable" to "uncomfortable. Based on the seat pan point vibration total value (ISO 2631-1), the UH-72 pilot station showed some level flight exposures that would cross the lower boundary of the Health Guidance Caution Zones into the potential health risks zone between 5 and 8 hours. None of the UH-72 crew chief exposures crossed the lower boundary in less than 8 hours. The UH-72 medic station showed that all level flight exposures would enter the potential for health risks zone between about 3.5 and 8 Hz. The HH-60M pilot and crew chief stations showed a majority of level fight exposures that would enter the potential health risks zone between 5 and 8 hours, and between 2 and 8 hours, respectively. The HH-60M medic station showed that all level flight exposures would enter the potential health risks zone between 1 and 5 hours, with higher airspeed records crossing the upper boundary between 4 and 8 hours, entering the zone where health risks are likely. This study emphasizes that rotary-wing aircraft generate multi-axis, higher frequency vibration above 10 Hz associated with exposing aircrew to the potential for health risks during normal missions.

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PREFACE

This report summarizes the vibration exposure assessment conducted on the HH-60M and UH-72 operated by the Vermont Army National Guard (VT ARNG) in accordance with the ISO 2631-1 (1997) Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements, ISO 2631-1 Amendment 1 (2010), and the MIL-STD-1472G Department of Defense Design Criteria Standard, Human Engineering (2012). A Memorandum of Understanding (MOU) was established among the US Army Institute of Public Health (AIPH), Vermont Army National Guard (VT ARNG), Army National Guard Bureau (NGB), and the 711 Human Performance Wing, Human Effectiveness Directorate (711 HPW/RH) that describes the roles and responsibilities associated with this activity. The occupational health nurse at VT ARNG contacted the US Army Public Health Command Region-North with regard to numerous reports she had received from the aircrew on back and neck discomfort, including cases where actual surgical and chiropractic treatments were undertaken. On 7 Feb 2013, the US Army Public Health Command Region-North, with permission from the NGB, contacted the AIPH Ergonomics Program to discuss the measurement of whole-body vibration on the aircrew at VT ARNG. AIPH contacted the 711 HPW/RH to assist with the measurements and assessment. The 711 HPW/RH and AIPH were key developers of an initiative proposed by the Defense Safety Oversight Council (DSOC) Human Systems Integration Task Force (HSI TF), Ad Hoc Working Group on Vibration, Discomfort, and Ergonomic Issues in High Speed Vessels, Aircraft, and Land Vehicles (AHWG), to formalize and expand the limited database of military-relevant vibration. This initiative was the first step in addressing science and technology gaps for the effective reduction of musculoskeletal discomfort and pain reported by rotary-wing/tilt-rotor aircrew. This study directly supported this initiative and was identified as Project 1. As part of this initiative, the 711 HPW/RH established itself as the Lead Test Organization (LTO) for this activity, in accordance with the AFRL Manual 99-103 (21 May 2007) AFRL Flight Test and Evaluation. The AIPH and 711 HPW/RH also developed a survey that was distributed to the VT ARNG aircrew to target discomfort/injury symptoms, aircrew discomfort/pain and vibration perception, posture, contributing factors, and ergonomic issues. The result of this survey will be documented in a separate report. Travel support for Project 1 was provided by the NGB.

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The authors also acknowledge Kenneth Forsythe, NGB, who provided the travel funds required to accomplish this study, and provided support with equipment configuration and data collection. Special thanks also goes to Frank Nitriansky and William Silvey, Army Aviation Engineering Directorate, for their work in acquiring the approved Air Worthiness Release for the equipment used to measure and collect the data onboard the aircraft.

Last, but certainly not least, the authors express their appreciation and special thanks to LTC John Johnston, Facility Commander, VT ARNG, and LTC Patricia Hammond, Occupational Health Nurse, VT ARNG, for the many months they spent advocating and guiding this project. Their leadership has culminated in a highly successful effort that will hopefully lead to the successful mitigation of discomfort and pain among rotary-wing/tilt-rotor aircrew.

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1.0 SUMMARY

This study characterized and assessed aircrew vibration during operation of the UH-72 Lakota and HH-60M Medevac located at the Vermont Army National Guard VT ARNG). The ISO 2631-1: 1997 was used as the guideline for the assessments.

Three portable battery-powered data acquisition units (DAUs) were used to collect accelerations at the pilot, crew chief, and medic stations on each aircraft. Triaxial accelerometer packs were attached to the floor or base of each seat. Triaxial acceleration pads were placed on top of the seat pan and seat back cushions at each station. Helmet mounts were attached to the top of the pilot and crew chief helmets to collection triaxial translational accelerations and to estimate helmet roll, pitch, and yaw. Data records were collected by aircraft task and the associated flight test conditions, including pre-departure checks, visual meteorological conditions (VMC), takeoff, hovering flight, VMC flight maneuvers, VMC approach, and terrain flight. The onboard test conductor prompted triggering of the DAUs to collect for 20 seconds once the aircraft was on a targeted condition. The acceleration spectra were estimated at each station and measurement site. The overall weighted accelerations were estimated in accordance with the ISO 2631. For assessing comfort reaction, the overall vibration total value (o*VTV)* was calculated as the vector sum of the weighted triaxial seat pan and seat back accelerations. For assessing health risks, the point vibration total value (*pVTV*) was calculated as the vector sum of the weighted triaxial seat pan accelerations.

For the UH-72 at all stations, measurement sites, and for most flight test conditions, a major peak was observed between 24 and 25 Hz in all three directions and was associated with the blade passage frequency (BPF). A small peak around 6 Hz was observed for some flight conditions and stations and associated with the propeller rotation frequency (PRF) of the aircraft. Additional peaks were also observed at multiples of the BPF. For the HH-60M at all stations, measurement sites, and for most flight conditions, a major peak was observed between 17-17.5 Hz and was associated with the BPF. Additional peaks were also observed at multiples of the BPF. While not easily identified, vibration associated with the PRF was estimated to be ~4-4.5 Hz, based on the BPF of the HH-60M. For both aircraft, the most substantial peak observed at the respective BPF did not necessarily occur in the vertical direction.

Comfort reactions (ISO 2631-1) for the UH-72, based on the *oVTV*, primarily ranged from “not uncomfortable” to “fairly uncomfortable”, depending on the station. Comfort reactions for the HH-60M, based on the *oVTV*, primarily ranged from “a little uncomfortable” to “uncomfortable”. For a few conditions at the crew chief and medic stations, the comfort reactions were even considered “very uncomfortable”. Comfort reactions are time independent.

The *pVTV* for health risk assessment used the level flight data at various airspeeds as mission representative to estimate the allowable duration (time) the crew member could be exposed to the respective condition before the vibration would be considered a potential health risk (assuming that the specific exposure does not change over time). This duration coincided with the lower boundary of the Health Guidance Caution Zones (HGCZ) (ISO 2631-1). The *pVTV* was also used to estimate the allowable duration of the exposure at the respective condition before the vibration was considered a likely health risk. This duration coincided with the upper

boundary of the HGCZ. The primary health risks identified by the ISO are lower back disorders, particularly to the lumbar spine.

For the UH-72 pilot station, the majority of level flight records showed exposures that would cross the lower boundary into the potential health risks zone between 5 and 8 hours at the higher airspeed of 120 KCAS. None of the exposures at the UH-72 crew chief station crossed the lower boundary in less than 8 hours. All level flight records at the UH-72 medic station showed exposures that would cross the lower boundary into the potential for health risks zone between about 3.5 and 8 hours. For the HH-60M pilot and crew chief stations, the majority of level flight records, particularly those at higher airspeeds, showed exposures that would cross the lower boundary into the potential health risks zone between 5 and 8 hours, and between 2 and 8 hours, respectively. All records at the medic station showed exposures that would cross the lower boundary between 1 and 5 hours, with several of the higher airspeed records crossing the upper boundary between 4 and 8 hours, into the zone where health risks are likely.

This study emphasizes that rotary-wing aircraft generate multi-axis, higher frequency vibration above 10 Hz associated with exposing aircrew to the potential for health risks during normal missions. However, the current assessment methodology is primarily based on biodynamic and psychophysical responses sensitive to lower frequency vibration that may underestimate exposure health risks based on weighted acceleration levels. The synergies and mechanisms by which posture, seats, and higher frequency vibration contribute to the health symptoms require investigation in order to develop or improve effective exposure criteria, ergonomic design requirements, and mitigation strategies. As a precaution, it is recommended that discomfort and health surveillance of aircrew be conducted and documented by health professionals and reported to the appropriate military health agencies and research institutes.

2.0 INTRODUCTION

Epidemiological surveys have consistently reported that ~85% of the rotary-wing aircrew surveyed have suffered back, leg, or neck pain associated with flying helicopters [1]. Poor posture, inadequate seats, and aircraft vibration have been targeted as contributing factors but their synergies and physiological mechanisms are unknown. The recent Business Case Analysis (BCA) conducted by R Cubed Consulting for the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD AT&L), and Office of the Deputy Under Secretary of Defense Installations and Environment (DUSD I&E) [1] emphasized that musculoskeletal pain and discomfort in these aircrew have a significant negative impact on mission effectiveness and mission readiness with an average yearly avoidable cost of $239 M. The strong recommendation in the BCA for improved seating systems cannot be effectively addressed without clear guidelines on exposure effects, seat design, and validation testing. However, appropriate science- and technology-based guidelines on exposure, seat design, and validation testing are non-existent, perpetuating the health issues.

The first step in addressing these deficiencies is to clearly characterize the actual multi-axis vibration exposure at several key occupant stations aboard various rotary-wing/tilt-rotor aircraft to identify the frequency components, acceleration magnitudes, and directions of the vibration entering the occupant at the occupant/vehicle interfaces (typically the seating system). In addition, there are guidelines provided in human vibration exposure standards that can be applied to these data for assessing the discomfort and health risk associated with the exposures [2, 3]. The health risk assessments conducted by the AFRL on a limited number of aircraft have suggested that aircrews may be subjected to potential health risks in less than three hours for occupational exposures [4-6]. The AFRL has also used these data to recreate the actual stressor environment in controlled laboratory testing for evaluating seat component influences, physiological responses, task performance, and task workload during simulated prolonged exposures. This approach can be used to investigate the relationships among the various contributing factors (i.e., posture, seats, vibration), and define the mechanisms that cause the reported symptoms. This type of exposure characterization can also help target harmful frequencies and exposure directions. As mentioned, these data are limited and have only recently been cleared for public release. What is not known is how similar the exposure characteristics and potential for health risks may be among current platforms.

Air Force, Army, and Navy members of the Defense Safety Oversight Committee (DSOC) Human Systems Integration Task Force (HSI TF) Ad Hoc Working Group on Vibration, Discomfort, and Ergonomic Issues in High Speed Vessels, Aircraft, and Land Vehicles (AHWG), developed several initiatives that target science and technology gaps for the effective reduction of musculoskeletal pain and discomfort reported by rotary-wing/tilt-rotor aircrew. The first initiative applies operational measurement techniques and assessment methodologies to formalize and expand the limited database of military-relevant vibration to include additional aircraft and occupant locations. The initiative leverages existing exposure standards to assess and compare discomfort and health risk among the platforms. In addition, a survey is included that focuses on the aircrew perception of discomfort/pain, vibration, and ergonomic issues contributing to their symptoms. The survey emphasizes problems with the seating system, posture, and vibration exposure, and what the occupant considers as the primary influences

contributing to their pain and possible performance degradation. This test program addresses step one described above and will provide the critical tools required to for follow-on initiatives that target health risk physiological mechanisms and equipment design for recommending mitigation strategies. The goal is to fill the science and technology gaps that have prevented the development of effective design requirements, formal equipment validation tests, and military-relevant exposure standards that ensure the health and safety of aircrew.

Project 1 of this flight test program targets the UH-72 Lakota and HH-60M Medevac operated by the Vermont Army National Guard (VT ARNG). The request for a vibration exposure survey was generated by the Safety and Occupational Health Office at VT ARNG to the National Guard Bureau (NGB) as well as the Army Institute of Public Health (AIPH). The occupational health nurse indicated that she had received numerous reports of back and neck discomfort from the aircrew, including cases where actual surgical and chiropractic treatments were undertaken. Whole-body vibration was targeted as a major influence on these symptoms. The Ergonomist at AIPH contacted the 711 HPW/RH as the Lead Test Organization (LTO) to support the vibration exposure assessment as part of the DSOC HSI TF AHWG first initiative. The project focused on assessing vibration exposure at selected aircrew stations and did not include any assessment of patient exposures. Travel funds for this effort were provided by NGB. Initial DSOC funds were provided to support test plan development and approval, equipment setup and sensor calibration, and initial data processing and analysis.

The AFRL 711 HPW/RH, as the LTO, prepared all required documentation including a Flight Test Plan, and conducted all required review boards including the Technical Review Board (TRB) and Safety Review Board (SRB), in accordance with AFRL Manual 99-103 AFRL Flight Test and Evaluation [7]. Air Worthiness Releases (AWRs) were obtained from the US Army Research, Development, and Engineering Command, Aviation Engineering Directorate (AED) for the two platforms. A Memorandum of Understanding was established among the US Army Institute of Public Health, Vermont Army National Guard, National Guard Bureau, and the Air Force Research Laboratory, 711 Human Performance Wing, Human Effectiveness Directorate that describes the terms and conditions of the collaborative effort.

This report focuses primarily on the discomfort and health risk assessments conducted on the UH-72 Lakota and the HH-60M Medevac. Additional reports may be generated that include more detailed analyses of the vibration characteristics associated with these platforms, including helmet motion. The aircrew survey results will also be presented in a separate report.

3.0 METHODS AND PROCEDURES

3.1 Aircraft and Measurement Locations

The rotary-wing aircraft targeted for Project 1 included the UH-72 Lakota (Tail Number 72059) and the HH-60M Medevac (Tail Number 201208) (Figure 1). Both aircraft are operated by the Vermont Army National Guard (VT ARNG). The HH-60M Medevac performs patient/casualty evacuations in both combat theaters and in the United States.   The aircraft can accommodate six patients. The UH-72 Lakota is a light utility helicopter configured for medical evacuations. It

Figure 1. a. UH-72 Lakota, b. HH-60M Medevac

can accommodate two pilots, two medics in rear-facing seats behind the pilot/co-pilot, and two stretchers.

On the UH-72, the measurement locations targeted for vibration characterization and health risk assessment included the pilot station located on the right side of the cockpit, the rearward-facing crew chief station located on the right side of the rear cabin immediately behind the pilot station, and the forward-facing medic station located at the back on the far left side of the rear cabin. On the HH-60M, the measurement locations targeted included the pilot station located on the right side of the cockpit, the crew chief station located on the right side at the back of the rear cabin, and the forward-facing medic station located on the left side at the back of the rear cabin. All stations were occupied by a pilot, co-pilot, crew chief, or test conductor.

3.2 Equipment, Instrumentation, and Measurement Sites

Three Remote Vibration Environment Recorders (REVERs), developed by the AFRL Human Effectiveness Directorate (711 HPW/RH), were used to collect multi-axis vibration data at each of the three aircrew stations. Each REVER, illustrated in Figure 2, consists of the following:

1. A 16-channel data acquisition unit (DAU) (Large or Small)
2. Two battery packs (Large and Small)
3. Triaxial accelerometer pack
4. Two triaxial accelerometer seat pads
5. One six-axis helmet mount (two REVER systems)
6. One trigger device
7. Connection/extension cables as required
8. Laptop computer

Specifications for the REVER components, including dimensions and weights, are listed in Appendix A, Table A-1.

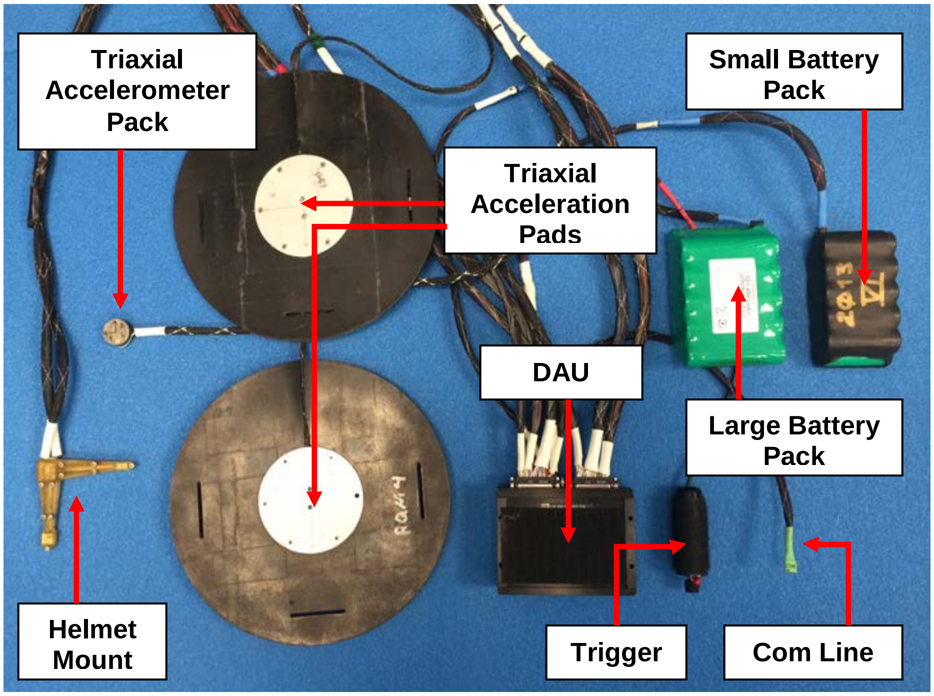

Figure 2. Remote Vibration Environment Recorder (REVER)

Tables 1 and 2 list the aircrew stations and measurement sites targeted for data collection, including the type of instrumentation for the UH-72 and HH-60M, respectively.

Table 1. UH-72 Measurement Sites and Type of Sensor

Station	Measurement Site	Instrumentation
Pilot Station (Right Side Cockpit)	Floor beneath seat pan	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
	Helmet	Six-Axis Helmet Mount
Crew Chief Station (Rearward-Facing, Right Side Rear Compartment behind Pilot Station)	Floor beneath seat pan	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
	Helmet	Six-Axis Helmet Mount
Medic Station (Forward-Facing, Left Side Back Rear Compartment)	Floor beneath of seat pan	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad

Table 2. HH-60M Measurement Sites and Type of Sensor

Station	Measurement Site	Instrumentation
Pilot Station (Right Side Cockpit)	Directly under seat pan	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
	Helmet	Six-Axis Helmet Mount
Crew Chief Station (Right Side Back Rear Compartment)	Seat mounting plate just behind seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad
	Helmet	Six-Axis Helmet Mount
Medic Station (Left Side Back Rear Compartment)	Seat mounting plate just behind seat	Triaxial Accelerometer Pack
	Seat Pan	Triaxial Acceleration Pad
	Seat Back	Triaxial Acceleration Pad

At the pilot and crew chief stations, the DAUs and batteries were carried in pockets attached on the outside of the survival vest. Figure 3 illustrates the vest configurations. In both aircraft, the smaller DAU (Appendix A, Table A-1) was carried by the pilot and located in a pocket attached

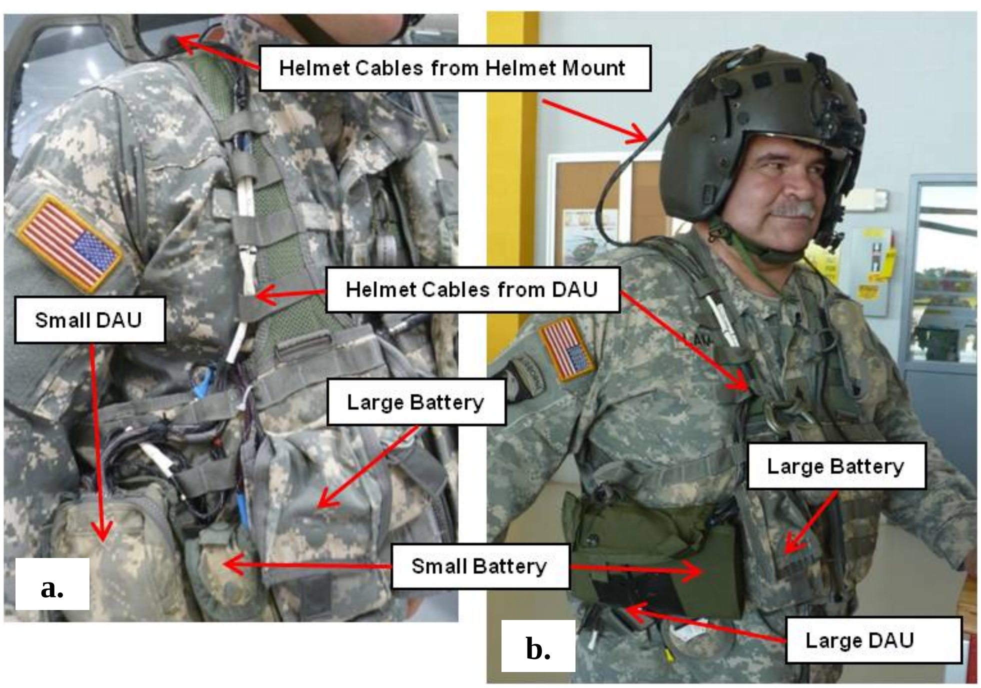

Figure 3. DAU and battery packs carried in survival vest at a. Pilot Station and b. Crew Chief Station

to the lower right side of the vest. One small battery pack and one large battery pack were carried in pockets attached next to the DAU pocket on the right side of the vest. In both aircraft, the larger DAU was carried by the crew chief and located in a pocket attached to the lower right side of the vest. One small battery pack was carried in the same pocket housing the DAU. One large battery pack was carried in a pocket attached next to the DAU pocket on the right side of the vest.

At the medic station, a large DAU was attached to the floor and one small and one large battery pack were attached to the top of the DAU. Figure 4 shows the attachment location in the UH-72 on the left side of the aircraft in front of the Medic seat next to the aircraft side wall. Figure 5 shows the attachment location in the HH-60M to the right of the medic seat.

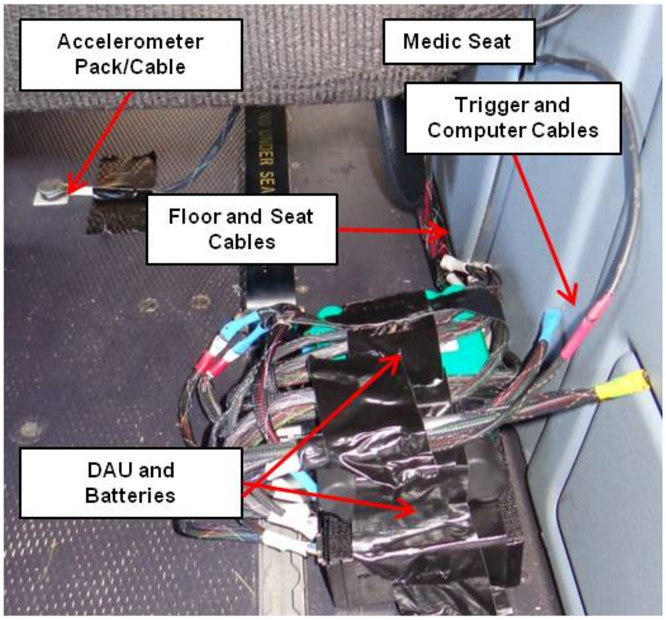

Figure 4. UH-72 Medic Station DAU, battery packs, and accelerometer pack mounted to floor

At each station, a triaxial accelerometer pack was used to measure the input acceleration (Fig. 2, Tables 1 and 2; Appendix A, Table A-1) in the fore-and-aft (X), lateral (Y), and vertical (Z) axis, relative to the seat/occupant orientation. Each pack consisted of three orthogonally-arranged miniature accelerometers embedded in a Delrin® cylinder. Double-sided mounting tape was used to secure the peak to the appropriate site. Triaxial accelerometer pads were used to measure the vibration transmitted to the occupant via the seat pan and seat back in accordance with the International Standards Organization, ISO-2631-1: 1997 Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-Body Vibration – Part I: General Requirements [2]. The pad consisted of a flat rubber disk with a triaxial accelerometer pack embedded in the center (Fig. 2; Appendix A, Table A-1). Double-sided adhesive tape and duct tape were used to secure the pads to the seat cushions (if present). Figures 6 and 7 illustrate the location of the floor/seat base triaxial accelerometer pack and the seat acceleration pads at the pilot station onboard the

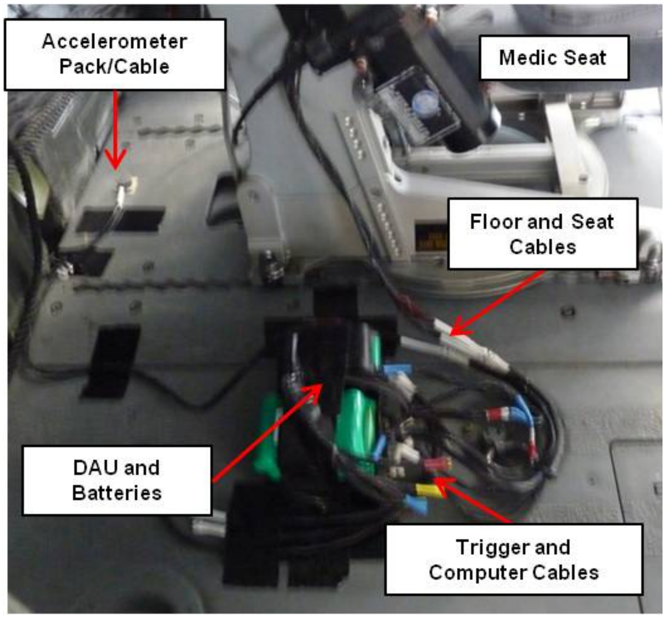

Figure 5. HH-60M Medic Station DAU and battery packs mounted to floor

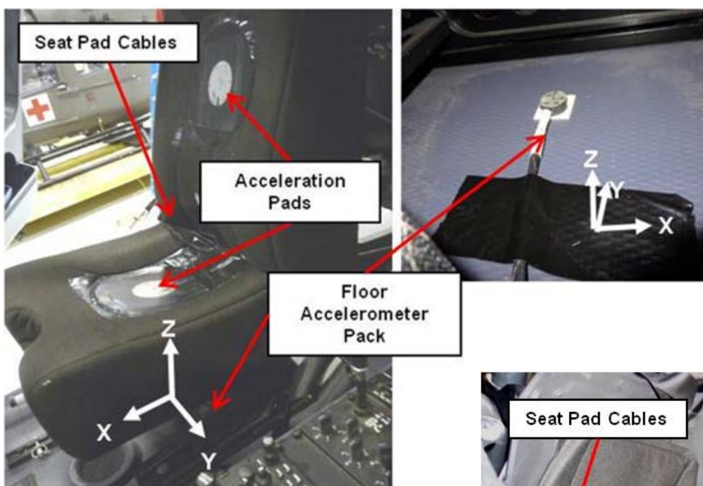

Figure 6. UH-72 Pilot Station accelerometer back and seat acceleration pads

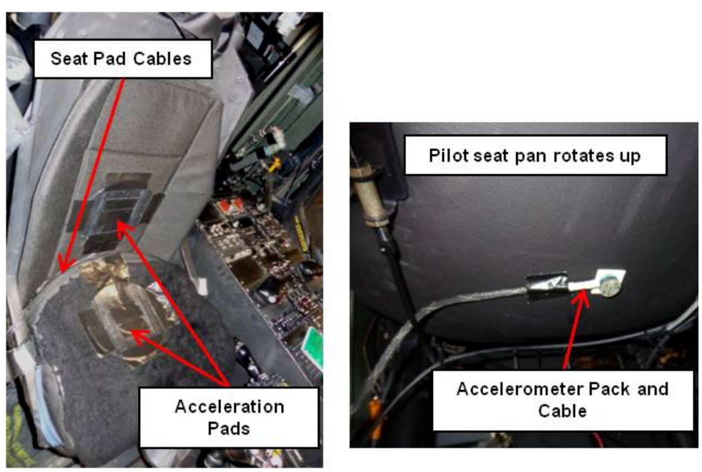

Figure 7. HH-60M Pilot Station accelerometer pack and seat acceleration pads

UH-72 and HH-60M, respectively. Figures 8 and 9 illustrate the location of the floor accelerometer and acceleration pads at the crew chief station onboard the UH-72 and HH-60M, respectively. Figure 10 illustrates the location of the seat acceleration pads at the medic station onboard the UH-72 and HH-60M. Figures 4 and 5 include the location of the floor accelerometer pack at the medic station onboard the two aircraft.

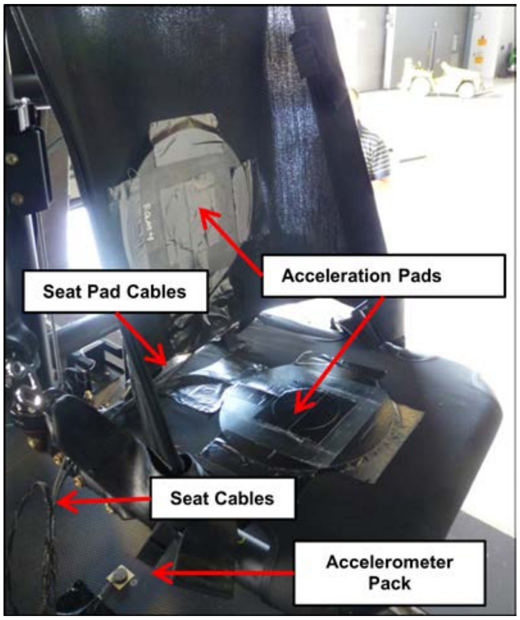

Figure 8. UH-72 Crew Chief Station accelerometer pack and seat acceleration pads

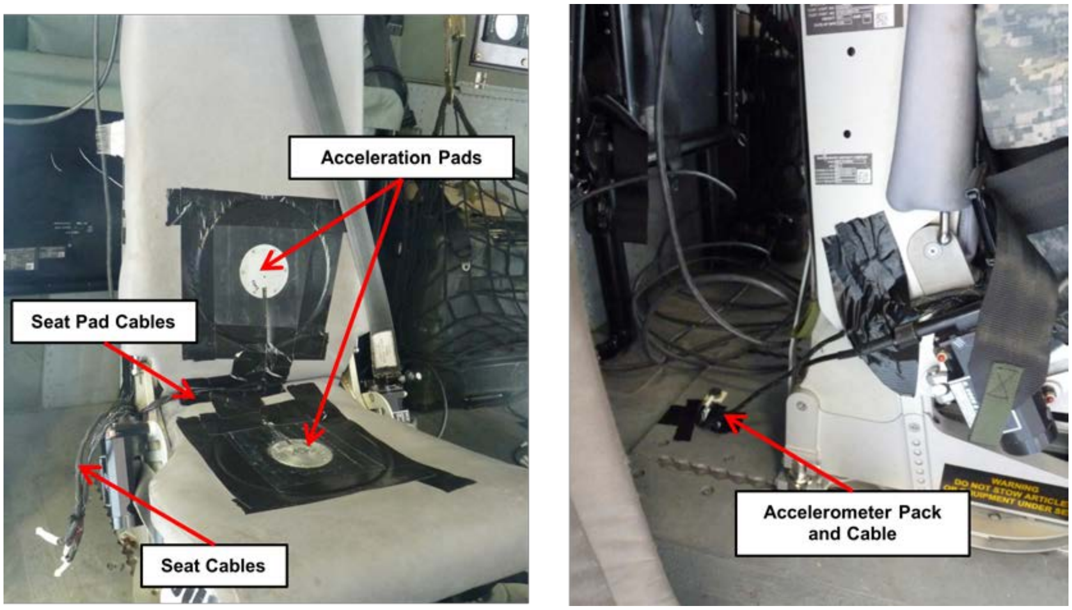

Figure 9. HH-60M Crew Chief Station accelerometer pack and seat acceleration pads

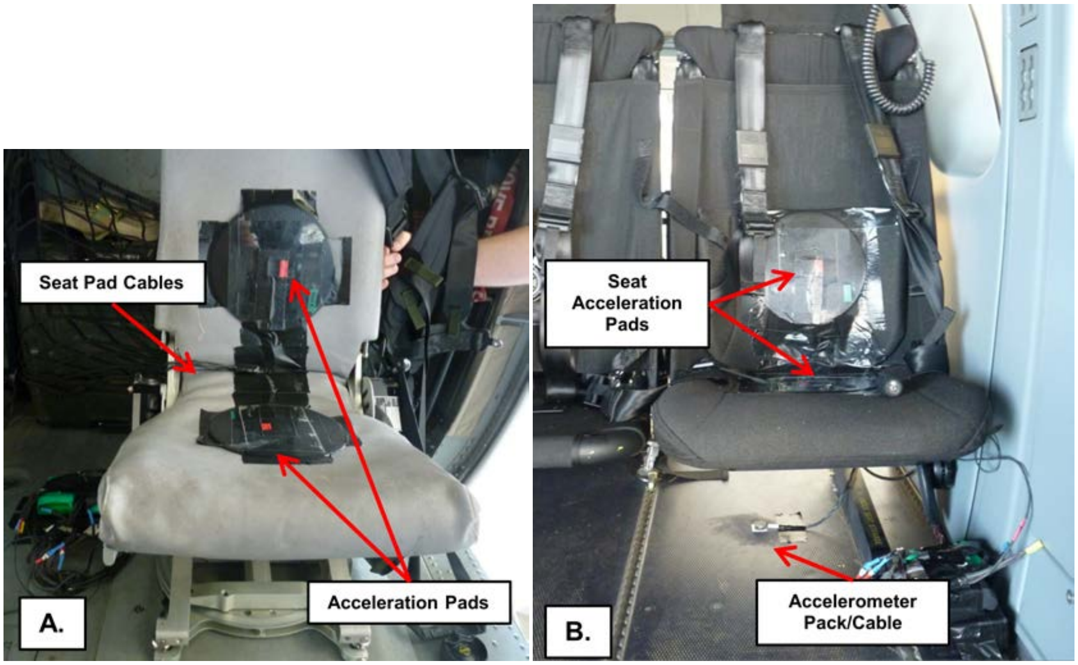

Figure 10. Medic Station seat acceleration pads. A. UH-72, B. HH-60M

A helmet mount was attached onto the top of the aircrew helmets located at the pilot station and crew chief station using double-sided mounting tape. Each helmet mount consisted of six miniature accelerometers strategically arranged to estimate helmet translations in the three orthogonal axies (X, Y, and Z) and helmet roll, pitch, and yaw (Appendix A, Table A-1). The helmet mount was further secured with duct tape to prevent any snags. Figure 11 illustrates the helmet mount (uncovered). Figure 12 illustrates the attachment of the helmet mount to the pilot and crew chief helmets prior to securing completely with duct tape. The configuration was similar for both aircraft.

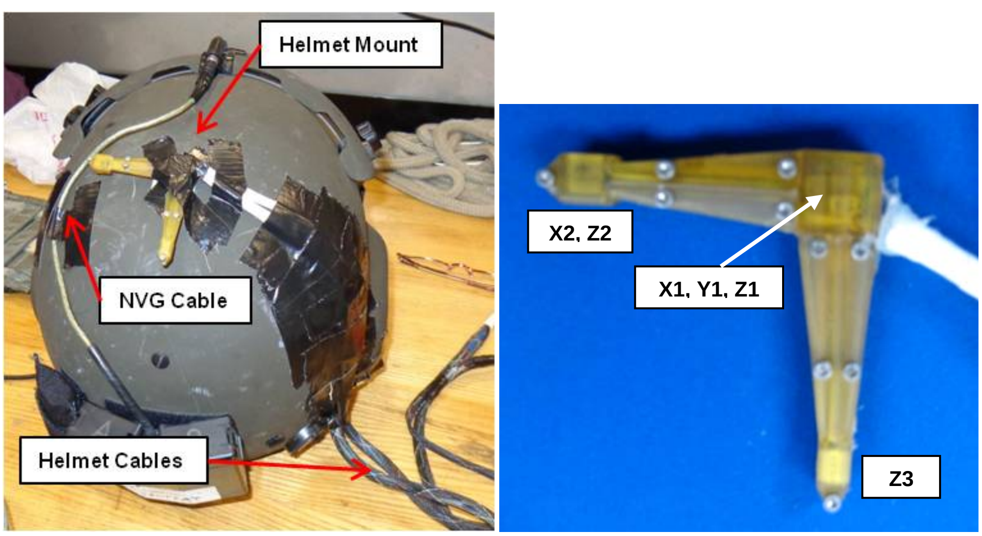

Figure 11. UH-72 and HH-60M Helmet Mount

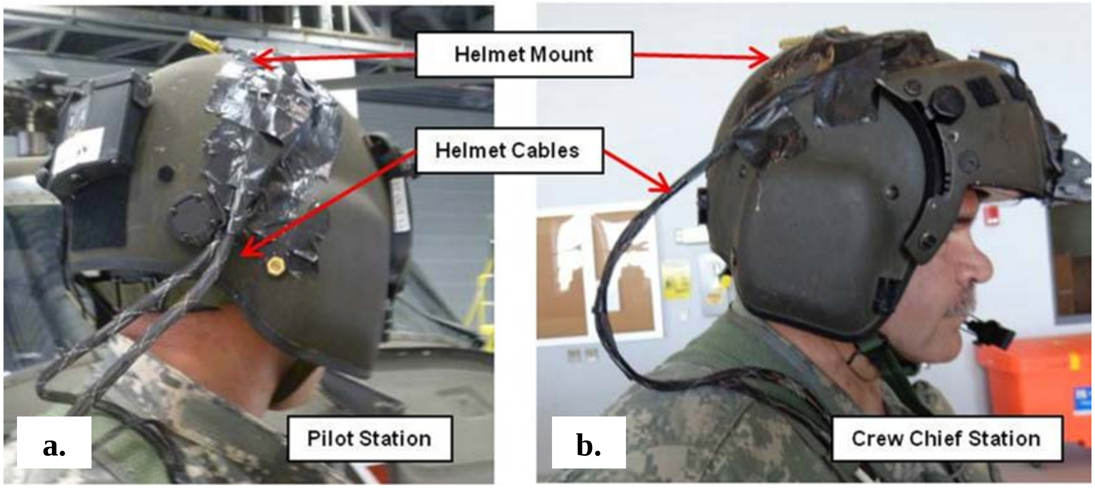

Figure 12. Helmet with attached mount a. Pilot b. Crew Chief

When using the survival vest, the seat accelerometer cables were connected to the DAU cables at the lower back edge of the vest on the pilot's right side and crew chief's right side on both the UH-72 and the HH-60M as illustrated in Figures 13 and 14, respectively. The cables were run beneath the lap belt to ensure no interference with the safety features of the aircraft or the occupant's task. The cables from the helmet were secured at the back of the helmet and run over the left or right shoulder to the DAU connection at the front of the vest as shown in Figure 3. All cable connections between the seat and helmet accelerometers and the DAU were made via break-away connectors. Each cable requires less than 21.8 N (4.9 pounds) of static weight to separate. The three-cable bundle shown in Figures 13 and 14 takes a peak force of 40 to 45 N (9 – 10 lbs) to separate when the occupant stands up (demonstrated in laboratory setting).

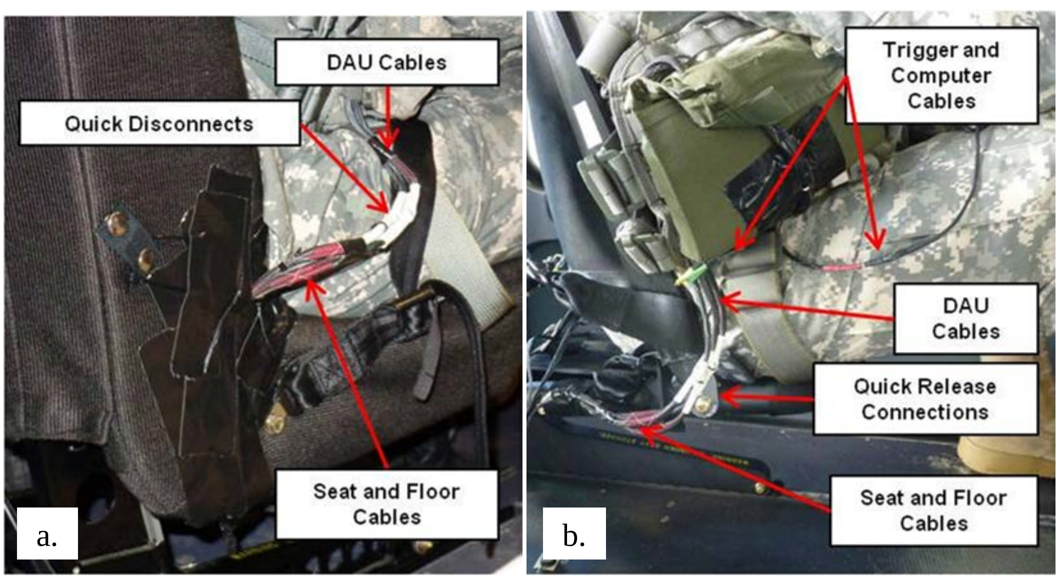

Figure 13. UH-72 Cable Connections a. Pilot b. Crew Chief

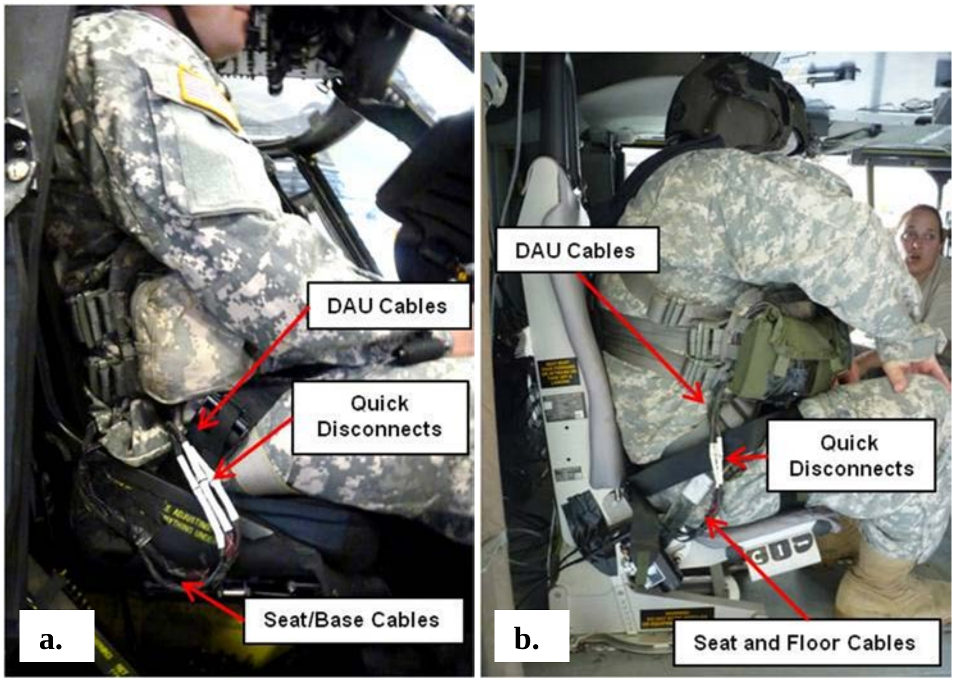

Figure 14. HH-60M Cable Connections a. Pilot b. Crew Chief

A triggering device (Fig. 2) was located at each occupant station to initiate data collection upon indication from an aircrew member that the aircraft was on a flight test condition. Once triggered, the DAU would collect data for a pre-specified amount of time. Prior to flight, a laptop computer was used to conduct sensor balance, calibration checks, and arming of each DAU. The computer was used to assign a specific sensor associated with a measurement site and direction to a channel in the DAU. Once armed, the computer was disconnected from the DAU. Upon return of the aircraft, the laptop was reconnected to the DAU and all channels downloaded for subsequent processing.

3.3 Data Collection, Processing, and Analysis

3.3.1 Data Collection.

Acceleration data were collected at the three aircrew stations and sites on both aircraft for the flight test conditions listed in Appendix A, Table A-2 Flight Test Records. The flight test conditions were organized relative to the specific flight tasks that were identified by the aircrew. Typically, the occupant of each station triggered the device to collect data at the respective station. For the HH-60M, a passenger located immediately behind the pilot station triggered data collection at the pilot station. One individual, typically the pilot, copilot, or occupant at the medic station, acted as the test conductor and prompted data collection once the pilot or copilot indicated that the aircraft was on the flight test condition. Multiple data records were collected for several of the conditions. Data records were collected throughout each flight and not necessarily collected in the order presented in Table A-2, depending on the mission. The designated test conductor insured that the data records were numbered consecutively in the order they were collected.

Fifteen channels of data were collected at each of the pilot and crew chief stations on both aircraft. Nine channels of data were collected at the medic station on both aircraft. Helmet data were not collected at the medic station (see Tables 1 and 2).

Once triggered, data were automatically collected for 20 seconds, filtered at 250 Hz, and digitized at 1024 samples per second. Upon return of the aircraft, the laptop was reconnected to each DAU and the time histories for each channel downloaded to the computer for processing.

Three flights were conducted on the UH-72. Flights 1 and 2 were conducted during daylight hours, while Flight 3 was conducted at night with the aircrew wearing Night Vision Goggles (NVGs). Two flights were conducted on the HH-60M. Flight 1 was conducted during daylight hours. Flight 2 was conducted in two parts: Flight 2a was conducted during daylight hours and Flight 2b was conducted at night with the aircrew wearing NVGs. Appendix A, Table A-3 lists the number of flight test condition records collected on each aircraft, for each flight, and for each condition.

3.3.2 Data Processing and Analysis.

A computer program developed by AFRL 711 HPW/RH was used to separate the 20-second records for each channel and assemble all channels for a particular record into a table of time histories. For each record, the time histories were processed using the MATLAB® Signal Processing Toolbox (The MathWorks, Inc., Natick, MA) to estimate the constant bandwidth spectral content. Using Welch's Method [8], each 20-second time history was divided into two-second sub-segments with a 50% overlap. A Hamming window was applied to each sub-segment and the resultant power spectral densities averaged over the 20-second period. The root-mean-square (rms) acceleration, a_{rms}, was calculated from the power spectral densities in 0.5 Hz intervals. The constant bandwidth rms acceleration spectra were used to locate the peak accelerations.

Each acceleration time history was also processed in one-third octave proportional frequency bands using a software program developed for MATLAB®[1]. The accelerations were reported at the center frequency of each respective one-third band. These data were used to assess the exposures in accordance with current standards.

With reference to Figure 11, the helmet roll rotation acceleration was estimated as the difference between the acceleration time histories measured at Z1 and Z2 divided by the moment arm (0.0508 m); pitch was estimated as the difference between the acceleration time histories measured at Z1 and Z3 divided by the moment arm (0.0508 m); and yaw was estimated as the difference between the acceleration time histories measured at X1 and X2 divided by the moment arm (0.0508 m). The rotation constant bandwidth accelerations were then calculated using the method described above.

The overall acceleration level, a, between 1 and 80 Hz was calculated for each station at the floor or seat base, seat pan, and seat back:

[1] Couvreur C (1997). FILTBANK - One-third-octave band frequency analyzer [computer program]. *MATLAB®*. Belgium: Faculte Polytechnique de Mons.

$$a = \left[\sum_i a_{rmsi}^2 \right]^{\frac{1}{2}} \quad (1)$$

where a_{rmsi} is the rms acceleration associated with the *ith* frequency component (in 0.5 Hz increments for constant bandwidth analysis, and at the center frequency of the one-third octave band for proportional bandwidth analysis). The overall translational and rotational helmet accelerations were also calculated as described above.

The assessment of discomfort (comfort reaction) and health risk followed the guidelines in ISO 2631-1 and the MIL-STD 1472G [2, 3]. The frequency weightings and multiplying factors listed in Table 3, based on human sensitivity to the location, frequency, and direction of vibration, were used to assess comfort reaction and health risk. Figure 15 illustrates the frequency weightings W_d, W_k, and W_c.

Table 3. ISO 2631 Frequency Weightings and Multiplying Factors (ISO 2631-1: 1997 [2])

	HEALTH RISK Seat Pan		COMFORT REACTION Seat Pan		Seat Back	
Direction	Frequency Weighting	Multiply Factor	Frequency Weighting	Multiply Factor	Frequency Weighting	Multiply Factor
X	W_d	$k = 1.4$	W_d	$k = 1.0$	W_c	$k = 0.8$
Y	W_d	$k = 1.4$	W_d	$k = 1.0$	W_d	$k = 0.5$
Z	W_k	$k = 1.0$	W_k	$k = 1.0$	W_d	$k = 0.4$

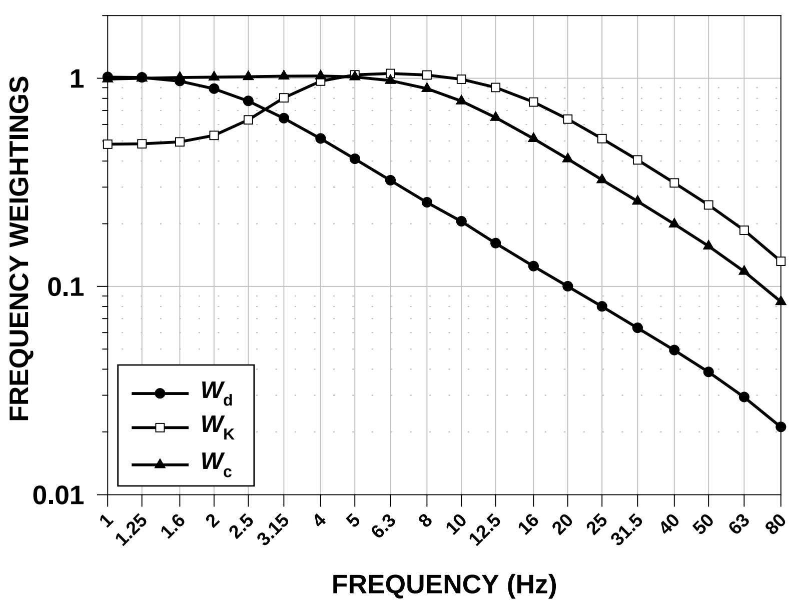

Figure 15. ISO 2631 Frequency Weightings W_d, W_k, and W_c (ISO 2631-1: 1997 [2])

The overall weighted rms acceleration level, a_w, was calculated between 1 and 80 Hz in each axis (X, Y, and Z) relative to the coordinate system of the seated occupant using the one-third octave rms accelerations:

$$a_w = \left[\sum W_{ij}^2 a_{rmsi}^2 \right]^{\frac{1}{2}} \tag{2}$$

where j represents the particular frequency weighting (d, k, or c) depending on the location and direction (Table 1), i represents the ith frequency component, and a_{rmsi} is the measured one-third octave acceleration level at center frequency i. For assessing comfort reaction, the point vibration total value (*pVTV*) was calculated at both the seat pan and seat back as the vector sum of the weighted fore-and-aft, lateral, and vertical accelerations, respectively, after applying the appropriate multiplying factors for the measurement location (seat pan or seat back):

$$pVTV = \left[k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2 \right]^{\frac{1}{2}} \tag{3}$$

The overall vibration total value (*oVTV)* was calculated as the vector sum of the seat pan and seat back *pVTVs*. The *oVTVs* were compared to the weighted accelerations associated with the comfort reactions given in ISO 2631-1: 1997, Annex C. The comfort reactions include “Not Uncomfortable”, “A Little Uncomfortable”, “Fairly Uncomfortable”, “Uncomfortable”, “Very Uncomfortable”, and “Extremely Uncomfortable”.

For assessing health risk, the highest weighted seat pan acceleration in any axis (fore-and-aft, lateral, or vertical) was used after applying the appropriate multiplying factors given in Table 3. The weighted data were compared to the ISO Health Guidance Caution Zones (ISO 2631-1: 1997, Annex B [2]). The ISO 2631-1: 1997 also states that the vector sum of the weighted accelerations at the seat pan (*pVTV*) after applying the appropriate multiplying factors for health risk can be used when vibration in two or more axes are similar. For weighted accelerations falling below the lower boundary of the ISO Health Guidance Caution Zones for the expected duration, health risks are unlikely. For those levels falling between the two boundaries, caution is given with respect to health risk, or there is a potential for health risk. For those levels falling above the upper boundary, health risks are likely for repeated occupational exposures. The MIL-STD 1472G [3], Section 5.5.5 Vibration and Shock, was also used in the assessment of health risk. While the MIL-STD 1572G uses the guidelines of the ISO 2631-1, for exposures of 3.5 hours and below, the lower boundary the Health Guidance Caution Zone follows the more conservative fourth power relationship described in the ISO Annex B.. Figure 16 illustrates the ISO Health Guidance Caution Zones and includes the lower boundary defined in the MIL-STD for exposures of 3.5 hours and below. The MIL-STD 1472G states the following:

> *“For exposures lasting 8.0 hours or less, the seat pan frequency weighted triaxial RMS accelerations in any orthogonal direction for any occupied space shall not fall within the zone labeled “Health Risk are LIKELY”. Preferably the weighted accelerations shall fall within the “minimal Risk to Health” zone”. For exposures lasting greater than 8.0 hours, the seat pan frequency weighted triaxial RMS accelerations shall not exceed 0.315 m/s^2. If the weighted*

accelerations fall within the "Caution Zone", a warning to occupants shall be provided indicating the potential health risk"

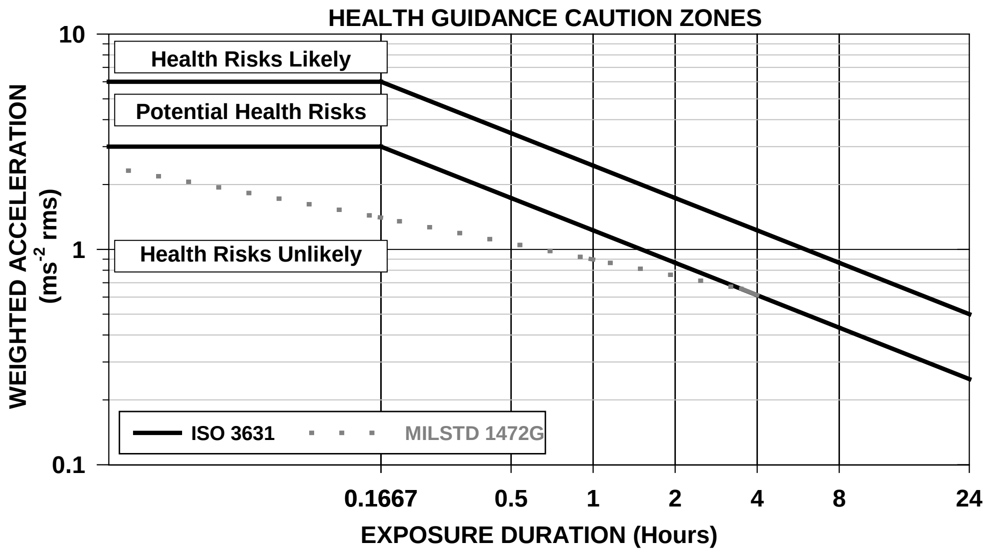

Figure 16. ISO 2631-1 Health Guidance Caution Zones
Plot includes more conservative lower boundary defined in MIL STD 1472G for exposures at 3.5 hours and below [2, 3]

4.0 RESULTS

All Figures and Tables referred to in this section are located in Appendix A.

4.1 Characteristics of the UH-72 and HH-60M Acceleration Spectra

For both platforms, it was expected that a peak in the acceleration spectra would occur in the vicinity of the main rotor speed of the aircraft. The frequency associated with the rotor speed is referred to as the propeller rotation frequency or PRF in this document. The highest peak was expected to occur at the blade passage frequency or BPF, which is predicted as the number of blades multiplied by the PRF. Both the PRF and BPF may vary slightly depending on the flight maneuver. Additional peaks were also expected at multiples of the BPF. The direction of the highest BPF was unknown prior to the analysis of these data. The following summarizes the observations of the spectral content, particularly for level flight. A more detailed analysis of the acceleration spectral characteristics and helmet motions will be included in subsequent technical reports and published documents.

4.1.1 UH-72 Acceleration Spectra.

Figures A-1 through A-3 illustrate the acceleration spectra for the UH-72 at the floor, seat pan, seat back and helmet (pilot and crew chief) for a selected data record collected during level flight at the pilot, crew chief, and medic stations, respectively. It was very difficult to identify a peak associated with the PRF. Figures A-1 and A-2 do show a small peak primarily in the lateral (Y)

direction at the floor, seat pan, and seat back. The peak occurs around 6 Hz, noting that the spectral analysis generates the responses in 0.5 Hz increments. The most notable peak, as expected, occurred between 24 and 25 Hz, and was associated with the BPF.

At the pilot station floor, the peak associated with the BPF tended to be the highest in the lateral (Y) direction, followed by a substantial peak in the vertical (Z) direction. In some records, these peaks were of similar magnitudes, as illustrated in Figure A-1. At the pilot station seat pan, the peak associated with the BPF was highest in the lateral (Y) direction at 80 KCAS, but tended to be more variable at the higher airspeeds, depending on the flight. There were records that showed similar peaks in all three directions at the higher airspeeds, as shown in Figure A-1. At the pilot station seat back, the peak associated with the BPF was highest in the vertical (Z) direction for most records, although there were instances where the magnitude of the vertical (Z) and lateral (Y) peaks were similar (Figure A-1). The lowest peak at the seat back occurred in the fore-and-aft (X) direction. At the pilot station helmet, the peak associated with the BPF was the highest in the vertical (Z) direction but was more dampened than the peaks observed at the the other measurement sites.

As shown in Figure A-1, a small but notable peak was observed around 49-50 Hz at all floor and seat measurement sites and was assumed to be a harmonic of the BPF (~2xBPF). This peak was very low at the helmet or not observed. Any accelerations at the helmet observed below 5 Hz were assumed to be due to voluntary head motions.

At the crew chief station floor, the peak associated with the BPF tended to be the highest in the lateral (Y) direction, followed by a substantial peak in the vertical (Z) direction, similar to the observations at the pilot station. At the crew chief station seat pan, the peak associated with the BPF was similar in all three directions at 80 KCAS. The lateral (Y) peak became notably higher in comparison to the other directions at 120 KCAS, as shown in Figure A-2. At the crew chief station seat back, the peak associated with the BPF tended to be the highest in the vertical (Z) direction, followed by the lateral (Y) peak at all three airspeeds. At the crew chief station helmet, the peak associated with the BPF was the highest in the vertical (Z) direction. The peak was more dampened as compared to the peaks at the other measurement sites.

As with the pilot spectra, a smaller but notable peak was observed around 49 to 50 Hz at all floor and seat measurement sites, which coincided with a harmonic of the BPF (~2xBPF). Again, this peak was very low or not observed in the helmet spectra.

At the medic station floor, seat pan, and seat back, the peak associated with the BPF tended to be highest in the lateral (Y) direction at all airspeeds. There were records that showed more similarity between the lateral (Y) and vertical (Z) peaks at the seat back, particularly at the highest airspeed (Figure A-3).

Some records showed the peak between 49 and 50 Hz, similar to the results for the pilot and crew chief stations, and was associated with a harmonic of the BPF (~2xBPF).

Observations of the spectral data for the other flight test conditions showed similar trends with respect to the frequency location of the peak responses. As with level flight, the highest peaks were typically observed at the BPF. In addition to level flight (Conditions L, M, and N), Ground Flight 100% (B), Climb (K), Std Rate Turn (O), Steep Rate Turn (P), and Descent (Q) showed the BPF primarily occurring between 24.5 and 25 Hz. A second peak associated with 2xBPF (49 – 50 Hz) was observed and quite prevalent for some test records. For Takeoff Normal (C), Takeoff Vertical (D), Takeoff Minimum Power (E), Hovering Stationary IGE (F), Hovering Taxis IGE (G), Hover OGE (H), Transverse Flow (I), Landing (J), Normal Approach OGE Hover (S), Steep Approach to OGE Hover (T), Normal Approach to IGE Hover (U), and Steep Approach to IGE Hover (V) the peak associated with the BPF occurring at a slightly higher frequency between 25.5 and 26 Hz. For these test records, the second peak associated with ~2xBPF was observed between 50 and 52 Hz, and quite prevalent in some test records. The BPF peak for Engine Idle occurred between 16 and 20 Hz, depending on the flight.

4.1.2 HH-60M Acceleration Spectra.

Figures A-4 through A-6 illustrate the acceleration spectra for the HH-60M at the floor or seat base, seat pan, seat back, and helmet (pilot and crew chief) for a selected data record collected during level flight at the pilot, crew chief, and medic stations, respectively. It was even more difficult to identify a peak associated with the PRF of the HH-60M as compared to the UH-72. As expected, the highest peaks tended to occur at what was presumed to be the BPF. These peaks consistently occurred between 17 and 17.5 Hz. Based on these observations, it was estimated that the PRF for level flight was between 4 to 4.5 Hz. Peaks can be identified at the helmet in this frequency range (Figures A-4 and A-5).

At the pilot station seat base, seat pan, and seat back, the peaks associated with the BPF were the highest in the lateral (Y) direction at 80 and 100 KCAS. The highest peak became prevalent in both the lateral (Y) and fore-and-aft (X) directions at 120 KCAS (Figure A-4). At the pilot station helmet, the highest peak associated with the BPF occurred in the vertical (Z) direction. Interestingly, for the illustrated record, the helmet vertical (Z) peak was high than at the other stations. One explanation is that the pilot helmet may have been in contact with the seat, or may have been associated with pitch motion caused by the fore-and-aft (X) motions at the seat pan and seat back.

At the pilot station, smaller peaks were observed at multiples of the BPF including 34 – 35 Hz (~2xBPF), 51 – 52 Hz (~3xBPF), and 68 – 70 Hz (~4xBPF), although these peaks were not observed at the helmet. In several cases, there was also a substantial peak between 78 and 80 Hz in the seat data. The source of this peak requires further spectral analysis and comparisons. The peaks beyond the BPF were not observed at the helmet. The accelerations at the helmet observed at low frequencies below 5 Hz were assumed to be due to voluntary head motions.

At the crew chief station floor, the peaks associated with the BPF were similar in magnitude in all three directions at the lower airspeed (80 KCAS) although the vertical (Z) peak tended to dominate most records. At the higher airspeeds, the vertical (Z) peak followed by the fore-and-aft (X) peak became notably more prevalent (Figure A-5). At the crew chief station seat pan, the peaks associated with the BPF were of relatively similar magnitude in all three directions at 80

KCAS. At the higher airspeeds, the fore-and-aft (X) peak was the most prevalent, followed by the vertical (Z) peak, for most records. At the crew chief station seat back, the peak associated with the BPF tended to be the most prevalent in the lateral (Y) direction at 80 KCAS. At the higher airspeeds, the peaks tended to be the highest in the fore-and-aft (X) and vertical Z) directions. At the crew chief station helmet, the peak associated with the BPF was the highest in the vertical (Z) direction. The peak was dampened as compared to the other measurement sites.

As with the pilot station, the crew chief station showed smaller peaks at multiples of the BPF including 34 – 35 Hz (~2xBPF), 51 – 52 Hz (~3xBPF), and 68 – 70 Hz (~4xBPF). For some data points, a very prevalent peak was observed in the vertical direction at 51 – 52 Hz. This peak was most prevalent at 80 KCAS. The peak between 78 and 80 Hz was also observed at the seat for some test records.

At the medic station floor, the peak associated with the BPF was the highest in the vertical (Z) direction at all three airspeeds. At the medic station seat pan and seat back, the peak associated with the BPF was the highest in both the vertical (Z) and fore-and-aft (X) directions (Figure A-6). Again, peaks associated with the PRF were either very low or not observed.

As with the pilot and crew chief stations, the medic station also showed smaller peaks at multiples of the BPF. As observed at the crew chief station, the vertical peak between 51 and 52 Hz was prevalent in some data records, particularly at 80 KCAS. The peak between 78 and 80 Hz was also observed for some test records.

Observations of the spectral data for the other flight test conditions showed similar trends with respect to the frequency location of the peak responses, except for Engine Ide (A). The highest peaks were typically observed at the BPF that occurred between 17 and 17.5 Hz. Smaller peaks were consistently observed at multiples of the BPF, including the generation of a peak between 78 and 80 Hz in some test records. For Engine Idle (A) at all stations and measurement locations, very small peaks were observed. The most notable occurred between 9.5 and 10 Hz, with various peaks observed at multiples of these frequencies.

4.2 Overall Unweighted and Weighted Acceleration Levels

The following sections present the overall unweighted and weighted acceleration levels averaged between 1 and 80 Hz for each flight test condition, in accordance with Eqs. (1) and (2), respectively. The overall weighted accelerations defined in Eq. (2) and described below in each direction were also multiplied by the appropriate multiplying factor listed in Table 3. It is cautioned that the summary provided below on the unweighted and weighted overall accelerations are observations and have not been statistically evaluated for significant effects of measurement site and direction.

As observed in the data for the various flight test conditions, the maximum accelerations tended to occur at very distinct frequencies associated with the aircraft propulsion system. The highest peak was associated with the BPF. For some records, substantial peaks were also observed at multiples of the BPF, with the highest tending to occur at 2*BPF. As mentioned for the HH-60M, the crew chief and medic stations showed substantial peaks at 3*BPF. In general, the high

magnitudes of the peaks associated with the BPF will have the greatest influence on the overall unweighted accelerations. For the overall weighted accelerations, the peaks will be weighted in accordance with Table 3 and Figure 15. Therefore, the higher frequency peaks will not have the influence on the overall weighted accelerations, as they do for the unweighted levels. The following sections 4.2.2 and 4.2.3 emphasize the effects of the frequency weightings and multiplying factors on the measured acceleration levels, since it is these weighted values that are used to assess comfort reaction and health risks in accordance with the current guidelines.

4.2.1 UH-72.

Figures A-7 to A-9 illustrate the pilot, crew chief, and medic stations mean overall unweighted accelerations ± one standard deviation at the floor, seat pan, and seat back for the various tasks and associated flight test conditions (records). Figures A-10 to A-12 illustrate the pilot, crew chief, and medic station overall weighted accelerations ± one standard deviation at the seat pan and seat back for the various tasks and associated flight test conditions.

At the pilot station (Figure A-7), the majority of records showed that the highest overall unweighted accelerations at the floor occurred in the lateral (Y) and vertical (Z) directions. The majority of the records showed that the highest unweighted accelerations at the pilot seat pan occurred in the lateral (Y) direction for most conditions, with dampening of the vibration in the vertical (Z) direction as compared to the floor. There also appeared to be higher levels of overall unweighted accelerations at the pilot seat pan in the fore-and-aft (X) direction as compared to the floor. The majority of the records showed that the highest overall unweighted accelerations at the pilot seat back occurred in the vertical (Z) direction, while the lowest occurred in the fore-and-aft (X) direction. The seat back vertical (Z) accelerations were higher than that observed at the seat pan.

At the crew chief station (Figure A-8), the majority of records showed that the highest overall unweighted accelerations at the floor occurred in the vertical (Z) direction followed by the overall levels in the lateral (Y) direction. As with the pilot station, the crew chief seat pan showed dampening in the overall unweighted accelerations in the vertical (Z) direction, and a tendency for higher fore-and-aft (X) accelerations as compared to the floor. The highest overall unweighted accelerations at the crew chief seat back occurred in the vertical (Z) direction, while the lowest overall levels occurred in the fore-and-aft (X) direction, similar to the trends observed at the pilot station. As with the pilot station, the seat back vertical (Z) accelerations were higher than that observed at the seat pan.

At the medic station (Figure A-9), the majority or records showed that the highest overall unweighted accelerations at the floor occurred in the lateral (Y) direction followed by the vertical (Z) direction. The highest overall unweighted levels at the seat pan occurred in the lateral (Y) direction, and were notably higher as compared to the floor, particularly for Task 1052. The unweighted vertical (Z) levels at the medic seat pan did not show as much dampening as compared to the floor as was observed at the other stations, but did show a tendency for increased fore-and-aft (X) vibration as compared to the floor. The lateral (Y) overall unweighted levels at the medic station seat pan were also notably higher as compared to the seat pan data at the other stations. The medic station also showed substantial overall unweighted accelerations in

the lateral (Y) direction at the seat back. Both the fore-and-aft (X) and lateral (Y) overall unweighted levels at the medic seat back were higher as compared to the other two stations.

Figures A-10, A-11, and A-12 illustrate the substantial reduction that occurs in the overall unweighted acceleration levels after applying the frequency weightings and multiplying factors listed in Table 3 and shown in Figure 15. In general, the highest overall weighted accelerations occurred in the vertical (Z) direction at the seat pan, and in the fore-and-aft (X) direction at the seat back at all stations.

Figure A-13 summarizes the mean unweighted and weighted overall accelerations at each station and in each direction at the seat pan and seat back for the UH-72 during level flight (80, 100, and 120 KCAS). Included are the *pVTVs* at the seat pan and seat back calculated in accordance with Eq. (3), as well as the *oVTV* (vector sum of *pVTVs* at seat pan and seat back) using the weighting curves and multiplying factors in Table 3 for Comfort Reaction. The figure also includes the *pVTV* at the seat pan using the weighting curves and multiplying factors in Table 3 for Health Risk. The figure shows the similarities between the directional effects in the peak responses observed at the BPF (Section 4.1.1) and the directional effects observed in the overall unweighted acceleration levels. Specifically, the figure depicts the tendency for higher unweighted accelerations at the seat pan in the lateral (Y) direction at all three stations, particularly at the medic station, and the higher unweighted accelerations at the seat back in the vertical (Z) direction at the pilot and crew chief stations. At the medic station, the lateral (Y) vibration tended to be higher or similar to the vertical (Z) vibration.

Figure A-13 shows that the weighted accelerations at the seat pan were higher in the vertical (Z) direction, while the weighted accelerations at the seat back were higher in the fore-and-aft (X) directions, as observed in Figures A-10 through A-12. These weighted accelerations appeared to be the major contributors to the *pVTV* at the respective measurement site. Figure A-13 also indicates that the *pVTV* tended to be higher at the seat pan as compared to the seat back at all three station: the *pVTV* at the seat back had only minimal effect on the *oVTV* calculation (i.e., *pVTV* at the seat pan was similar to *oVTV*).

4.2.2 HH-60M.

Figures A-14 through A-16 illustrate the pilot, crew chief, and medic stations mean overall unweighted accelerations ± one standard deviation at the floor, seat pan, and seat back, respectively, for the various tasks and associated flight test conditions. Figures A-17 to A-19 illustrate the pilot, crew chief, and medic station overall weighted accelerations ± one standard deviation at the seat pan and seat back for the various tasks and associated flight test conditions.

It was more difficult to identify consistent directional effects across the various tasks and flight test conditions for the HH-60M. In general, at the pilot station, the unweighted levels tended to be the highest in the fore-and-aft (X) and lateral (Y) directions at the seat base and seat pan, with the directional effects being more variable at the seat back. While not determined statistically, the unweighted acceleration levels at the seat back appeared to be very similar among the three measurement sites.

In contrast, at the crew chief station, the overall unweighted accelerations tended to be the highest in the vertical (Z) direction at the seat base. The acceleration levels tended to be more similar at the seat pan. The crew chief seat back accelerations tended to be the highest in the vertical (Z) direction and similar to the trends observed at the floor.

At the medic station, the overall unweighted acceleration levels were notably higher in the vertical (Z) direction at the floor, with the lowest levels observed in the lateral (Y) direction, particularly for Task 1052. The medic station seat pan and seat back levels were amplified in the fore-and-aft (X) direction as compared to the floor and more similar to the overall unweighted accelerations in the vertical (Z) direction. The lateral (Y) accelerations were notably the lowest at all three measurement sites for most records.

As with the UH-72, Figures A-17 to A-19 show the significant reduction in the overall unweighted acceleration levels after applying the weighting curves and multiplying factors listed in Table 3. The highest weighted accelerations at all three stations on the HH-60M occurred in the vertical (Z) direction at the seat pan, and in the fore-and-aft (X) direction at the seat back, similar to the UH-72 observations.

Figure A-20 summarizes the mean unweighted and weighted overall acceleration data at each station and in each direction at the seat pan and seat back for the HH-60M during level flight (80, 100, and 120 KCAS). Included are the *pVTV*s at the seat pan and seat back calculated in accordance with Eq. (3), as well as the *oVTV* using the weighting curves and multiplying factors in Table 3 for Comfort Reaction. The figure also includes the *pVTV* at the seat pan using the weighting curves and multiplying factors in Table 3 for Health Risk. As with the UH-72, the figure shows the similarities between the directional effects in the peak responses observed at the BPF (Section 4.1.2) and the directional effects observed in the unweighted and weighted overall acceleration levels. Specifically, the figure depicts the tendency for higher unweighted accelerations at the pilot station seat pan in the fore-and-aft (X) and lateral (Y) directions, and similar unweighted acceleration levels at the seat back. The figure also shows the tendency for similar unweighted acceleration levels at the crew chief station seat pan in all three directions, with the highest unweighted accelerations at the seat back occurring in the vertical (Z) direction. The highest unweighted accelerations at the medic seat pan and seat back occurred in both the fore-and-aft (X) and vertical (Z) directions.

Figure A-20 shows that the weighted accelerations at the seat pan were higher in the vertical (Z) direction, while the weighted accelerations at the seat back were higher in the fore-and-aft (X) directions, as shown in Figures A-17 through A-19, and similar to the results for the UH-72. Figure A-13 also indicates that the *pVTV* tended to be higher at the seat pan as compared to the seat back at all three station: the *pVTV* at the seat back had only minimal effect on the *oVTV* calculation (i.e., *pVTV* at the seat pan was similar to *oVTV*), similar to the results for the UH-72.

4.3 Aircrew Vibration Comfort Assessment

The guidelines in ISO 2631-1 [2] were used to assess the Comfort Reactions of the aircrew based on the *oVTV* calculated as the vector sum of the *pVTVs* estimated at the seat pan and seat back in

accordance with Eq. (3) and using the frequency weightings and multiplying factors in Table 3. The Comfort Reactions are independent of time.

4.3.1 UH-72.

Figures A-21 through A-23 illustrate the *oVTV* estimated for each test record, flight test condition, and flight number at the pilot, crew chief, and medic stations, respectively, aboard the UH-72. Included are the mean values ± one standard deviation. In general, the *oVTV* estimated for the UH-72 were primarily associated with being "not uncomfortable" to "a little uncomfortable" in accordance with the ISO 2631 guidelines on comfort reactions. The crew chief station showed a couple of records with exposures that would be considered "fairly uncomfortable", particularly for Task 1058. The medic station showed a majority of records for Task 1052 with exposure levels that would be considered "fairly uncomfortable". Figure A-13 does show a slightly higher mean value for the medic *oVTV* for comfort reaction during level flight. The overall weighted accelerations shown in Figures A-10 through A-12 for Task 1052 (that includes level flight) do show the relatively higher mean overall weighted lateral (Y) and vertical (Z) seat pan accelerations and the relatively higher overall weighted fore-and-aft (X) seat back accelerations observed at the medic station as compared to the other stations. These higher levels would have contributed to the higher *oVTV*.

4.3.2 HH-60M.

Figures A-24 – A26 illustrate the *oVTV* estimated for each test record, flight test condition, and flight number at the pilot, crew chief, and medic stations, respectively, aboard the HH-60M. Included are the mean values ± one standard deviation. In general, the *oVTVs* estimated for the HH-60M were higher as compared to the UH-72. At all stations, the estimated *oVTV* indicated that the comfort reaction was at least "a little uncomfortable" to "fairly uncomfortable". At all three stations, certain records showed that some exposures were considered "uncomfortable" in accordance with the ISO 231 guidelines, particularly at the crew chief and medic stations for Task 1052. The crew chief and medic stations also showed records associated with exposures that would be considered "very uncomfortable", particularly for Task 1052 steep rate turn and descent. Figure A-20 shows that the mean weighted vertical (Z) accelerations at the seat pan for level flight were the highest at the medic station and lowest at the pilot station. The mean *oVTVs* for comfort reaction (Fig. A-20) showed the same trend. Comparing the overall weighted seat pan and seat back accelerations among the pilot, crew chief, and medic (Figs. A-17 – A-19), the higher *oVTVs* observed at the crew chief and medic stations were primarily the result of the higher overall weighted vertical (Z) seat pan accelerations.

4.4 Health Risk

The guidelines in ISO 2631-1: 1997 and MIL-STD 1472G were used to assess the aircrew health risk due to vibration exposure based on the *pVTV* at the seat pan, using the frequency weightings and multiplying factors listed in Table 3. The exposures associated with level flight were used for the assessment. This approach was used since mission time can vary, as well as the amount of time the aircrew would spend at a particular flight condition. The level flight test conditions were determined to be a good representation of the average vibration exposure levels experienced during any particular mission. This was based on previous assessments, and the weighted vibration levels observed for all flight test conditions targeted in this study. If the time

spent at each of the various flight conditions are known during a mission, the *pVTV* can be calculated using the exposure levels and durations. Figures A-27 and A-29 include plots of the ISO 2631 Health Guidance Caution Zones and show the more conservative boundary defined in the MIL-STD 1472 for exposures below 3.5 hours. The plots emphasize exposure times between 1 and 10 hours, with a line marking the 8-hour exposure duration. Tables A-4 through A-9 list the overall unweighted and weighted seat pan accelerations in each direction, as well as the *pVTV* calculated for assessing health risks for all stations aboard both aircraft based on the level flight records at airspeeds of 80, 100, and 120 KCAS. Data are also included for the AVCS OFF and NOE flight test conditions aboard the HH-60M. The tables also list the durations allowable, in hours, before the exposure associated with the listed record would enter the lower boundary and upper boundary of the Health Guidance Caution Zones (HGCZ) illustrated in Figure 16, and Figures A-27 and A-29. These exposure durations are based on the highest overall acceleration level in any direction, as well as the seat pan *pVTV* for health risk. The highest weighted acceleration at the seat pan always occurred in the vertical (Z) direction, regardless of the aircraft or station. Any greater exposure duration for that particular maneuver and record would enter the zone where there is the potential for health risks or where health risks are likely. The durations were calculated based on the square root time dependency. The durations and associated acceleration levels are color-coded (orange and red) to easily identify which maneuvers and records would cross the two boundaries in less than 8 hours.

4.4.1 UH-72.

Figure A-27 includes lines representing the values of the seat pan *pVTV* for all level flight records at the three airspeeds, for each flight, and for each aircrew station aboard the UH-72. The lines emphasize where the exposures cross into the zone where there is the potential for health risks. This assumes that the rms acceleration exposure level estimated over a 20-second period for that particular flight test condition and record would not change over longer exposure duration. As noted in the figure, at all three stations showed a tendency for the *pVTV* to increase with airspeed. This can also be observed to some extent in the plots of the comfort reactions (Figs. A-21 – A-23). Figure A-27 shows that there were several exposures at the pilot station where the acceleration levels would cross the lower boundary just under 8 hours, particularly if flying at 120 KCAS. Figure A-27 shows that none of the exposures at the crew chief station would cross into the zone where there is the potential for health risks in less than 8 hours. In contrast, all of the level flight exposures at the medic station crossed into the zone where there is the potential for health risk between about 3.5 hours and 8 hours.

Table A-4 clarifies that, between 5 and 8 hours of exposure at the UH-72 pilot station, all level flight records at 120 KEAS (except for one) would cross the lower boundary and enter the potential for health risks zone based on the seat pan *pVTV*. Very few of these exposures would exceed 8 hours when based on the overall weighted vertical (Z) seat pan acceleration, suggesting a substantial contribution of horizontal vibration to the *pVTV*.

Table A-5 clarifies that none of the UH-72 crew chief station level flight records would reach the potential for health risks in less than 8 hours of exposure.

Table A-6 clarifies that, between about 3.5 and 8 hours of exposure at the UH-72 medic station, all level flight records would enter the potential for health risks zone based on the *pVTV*. A

majority of the records collected at 120 KEAS would also enter the zone between 4 and 8 hours based on the overall weighted vertical (Z) acceleration.

Figure A-28 shows plots of the mean exposure durations required (± one standard deviation) among the UH-72 flight test conditions (listed in Tables A-4 through A-6) to reach the lower boundary of the HGCZ, beyond which there is the potential for health risks based on the weighted vertical (Z) seat pan acceleration and the seat pan *pVTV*. The figure illustrates the effect of using the weighted vertical (Z) seat pan acceleration vs the seat pan *pVTVs* to assess health risks relative to the station.

4.4.2 HH-60M.

Figure A-29 includes lines representing the values of the seat pan *pVTV* for all level flight records at the three airspeeds, for each flight, and for each aircrew station aboard the HH-69M. Again, the assumption is made that the rms acceleration exposure level estimated over a 20-second period for that particular flight test condition and record would not change over longer exposure durations. As with the UH-72, there was a tendency for the *pVTV* to increase with airspeed. This trend can also be observed to some extent in the plots of the comfort reactions (Figs. A-24 – A-26). Figure A-29 shows that quite a few records collected at the pilot station were associated with exposures that would enter the lower boundary, where the potential for health risks exist, in less than 8 hours, particularly at the higher airspeeds. Figure A-29 shows that the exposure levels associated with level flight at the crew chief station were quite variable, with most of the records associated with the higher airspeed (120 KCAS) entering the zone of potential health risks in less than 8 hours. Several records associated with exposures at the higher airspeed appeared to cross the lower boundary in as little as 2 hours. It also appeared that several exposures would actually enter the zone where health risks are likely by 8 hours. Figure A-29 shows that the exposure levels associated with level flight at the medic station were variable. All level flight records were associated with exposures that would enter the potential for health risks zone in less than 8 hours, most would enter the zone by 5 hours of flight. Many of the exposures at the higher airspeed (120 KCAS) also entered the health risks likely zone in less than 8 hours.

Table A-7 clarifies that, between about 5 and 8 hours of exposure at the HH-60M pilot station, several records at 100 KEAS, all records at 120 KEAS, and all but one record for NOE would cross the lower boundary and enter the potential for health risks zone based on the *pVTV*. A majority of the records at 120 KEAS would cross the lower boundary zone in less than 8 hours based on the overall weighted vertical (Z) acceleration. Both records for AVCS OFF would cross the lower boundary in as little as 2 hours of exposure, with one record that would cross the upper boundary in about 8 hours and enter the health risks likely zone (based on the *pVTV*).

Table A-8 clarifies that, between 2 and 8 hours of exposure at the HH-60M crew chief station, a few records at 100 KEAS and almost all records at 120 KEAS would cross the lower boundary and enter the potential for health risks zone based on the *pVTV*. A majority of the records at 120 KEAS would also cross the lower boundary in less than 8 hours based on the overall weighted vertical (Z) acceleration. Both records for AVCS OFF would cross the lower boundary in less than 2 hours. A couple of records at 120 KEAS and both records for AVCS OFF would cross the upper boundary in just under 8 hours and enter the health risks likely zone.

Table A-9 clarifies that, between 1 and about 5 hours of exposure at the HH-60M medic station, all level flight records, both ACVS OFF records, and all NOE records using both the *pVTV* and overall weighted vertical (Z) acceleration would cross the lower boundary and enter the potential for health risks zone. In addition, a couple of the records at 100 KEAS, the majority of the records at 120 KEAS, and both records at ACVS OFF show that the medic would cross the upper boundary between 4 and 8 hours and enter the health risks likely zone, based on either the *pVTV* or the overall weighted vertical (Z) acceleration.

Figure A-30 shows plots of the mean exposure durations required (± one standard deviation), among the HH-60M flight test conditions (listed in Tables A-7 – A-9), to reach the lower boundary of the HGCZ beyond which there is the potential for health risks based on the weighted vertical (Z) seat pan acceleration and the seat pan *pVTV*. The figure illustrates the effect of using the weighted vertical (Z) seat pan acceleration vs the seat pan *pVTVs* to assess health risks relative to the aircrew station.

5.0 DISCUSSION AND CONCLUSIONS

This document provides a summary of the vibration exposure assessment conducted onboard the UH-72 Lakota and HH-60M Medevac helicopters. Included is a synopsis of the seat pan and seat back acceleration spectra generated by these aircraft. The characteristics of the spectra generated by these aircraft were similar to that observed during other investigations conducted on rotary-wing and tilt-rotor aircraft, where the highest accelerations were associated with the propulsion system and occurred at relatively distinct frequencies [4, 5, 6]. The vibration associated with the propeller rotation frequency or PRF was typically quite low in magnitude and occurred below 10 Hz for both aircraft. The highest vibration tended to occur at the blade passage frequency or BPF beyond 10 Hz at all measurement sites on both aircraft, with additional peaks observed as harmonics of the BPF. Peak magnitudes were observed in the fore-and-aft (X), lateral (Y), and vertical (Z) directions, depending on the flight test condition, station, and measurement site.

As shown in Figures A-13 and A-20, the higher frequencies associated with the UH-72 and HH-60M, as with other rotary-wing/tilt-rotor aircraft, can be highly weighted once the ISO 2631-1 frequency weightings and multiplying factors are applied for calculating the overall weighted accelerations, *pVTVs*, and *oVTVs*. This can dramatically reduce the contribution of the vibration to the comfort reaction and health risk calculation defined in the standard. Regardless, both aircraft did show that certain flight test conditions were associated with comfort reactions ranging from being considered ‘fairly uncomfortable’ to even ‘very uncomfortable’ depending on the station. Both aircraft also showed that level flight exposures can cross into the potential for health risk zone, and even enter the health risk likely zone (HH-60M) in less than 8 hours. The health risk assessment and the calculation of the allowable exposure durations before entering the potential for health risk zone were based on the Health Guidance Caution Zones or HGCZ defined in ISO 2631-1, and not the more conservative lower boundary given in the MIL-STD 1472G [3]. As illustrated in Figure A-29 for the HH-60M crew chief and medic stations,

several of the level flight records would cross the lower boundary in even less time for durations of less than 3.5 hours when using the military guideline.

The exposures aboard the UH-72 tended to show less effect on discomfort and health risk as compared to the HH-60M. For example, the mean allowable duration before crossing the lower boundary at 120 KCAS was 6.9 hours, 12.5 hours, and 4.5 hours at the UH-72 pilot, crew chief, and medic stations, respectively (Tables A-4 – A-6), compared to 5.7 hours, 4.3 hours, and 1.7 hours at the HH-60M pilot, crew chief, and medic stations, respectively (Tables A-7 – A-9). Without a more detailed comparison of the directional effects and peak magnitudes, it is difficult to pinpoint the contributing factors for these differences. While the peak accelerations associated with the higher frequency responses aboard the UH-72 would be weighted more as compared to the HH-60M (note frequency weightings in Figure 15 associated with BPF at center frequencies 16 and 25 Hz), the direction of the peak responses can play a substantial role. As an example, Figure A-31 compares the overall unweighted and weighted accelerations in each direction at the pilot station aboard the two aircraft at 120 KCAS level flight. The figure shows that both aircraft produced similar unweighted and weighted seat pan acceleration levels in the vertical (Z) direction. The major difference occurred in the fore-and-aft (X) direction, with higher levels observed at the HH-60M pilot station. Regardless, the strong influence of the weighted vertical (Z) component resulted in a relatively similar *pVTV* value for health risks with approximately 1 hour difference in the allowable exposure duration to the lower boundary of the HGCZ, as noted above (6.9 hours compared to 5.7 hrs). However, at the seat back, even though the UH-72 pilot station showed notably higher unweighted vibration levels in the lateral (Y) and vertical (Z) directions, the higher fore-and-aft (X) vibration at the HH-60M pilot seat back, in combination with the seat back frequency weightings and multiplying factors, produced the highest weighted seat back accelerations in the fore-and-aft (X) direction at the HH-60M pilot station. This contributed to the higher *oVTV* at the HH-60M pilot station for assessing comfort reaction (Fig. 31). At the medic stations, even though there was very substantial vibration in the lateral (Y) direction at the seat pan on the UH-72, the dominance of the weighted seat pan vertical (Z) vibration on the HH-60M resulted in a substantially higher *pVTV* for assessing health risk, as compared to the UH-72 (Fig. 31). At the seat back, while the unweighted and weighted acceleration levels in the vertical direction (Z) were similar between the two aircraft, the influence of the relatively high fore-and-aft (X) vibration at the HH-60M medic station resulted in higher weighted seat back accelerations. As with the pilot stations, this contributed to the higher *oVTV* at the HH-60M medic station as compared to the UH-72 (Fig. 31). Similar trends were also observed at the crew chief stations (Fig. 31).

Differences in the vibration levels between the two aircraft at a respective station, as well as differences between the vibration levels among the stations, were most likely influenced by the seating system and occupant. The seating systems differed in the attachment, adjustments, and the type and extent of cushion and lumbar support between the two aircraft and among the stations. The occupants were of different stature and posture. The only station that included the same occupant for all flights on both aircraft was the medic station. This station or was occupied by the test conductor for all flights on both aircraft. Therefore, the major influence on any differences at the medic stations would be primarily due to the seating system structure, location, and vibration characteristics of the aircraft, noting that the seat itself could have a major effect on the occupant posture. All of these factors can influence the transmission of vibration to the

occupant, as well as influence other musculoskeletal activity unrelated to the presence of vibration. These are factors that are not easily investigated in the operational environment but can be studied in the laboratory setting with the appropriate exposure simulation facilities, seating systems, and a broad range of subject anthropometries.

The assessment guidelines provided in the standards are based on human physical and psychophysical (perceptional) responses to the frequency, magnitude, and direction of the vibration exposure. These response characteristics are expressed by the frequency weightings and multiplying factors that are applied during the assessment process. Humans are the most sensitive to vibration occurring below 10 Hz, particularly in the vertical (Z) direction. Vibration at these lower frequencies can produce relative motions between body regions (vertical motion) and cause postural instabilities (when combined with low frequency horizontal motion) that are readily perceived as being uncomfortable and even painful. Whole-body resonance has been identified during vertical vibration occurring between 4 and 8 Hz, where the large relative motions between the upper and lower torso transmit easily to the head. The comfort reactions defined in ISO 2631-1 (Appendix C) [2] are based on passenger expectations in public transportation, where exposures are expected to occur at lower frequencies and shorter durations than in military operations. Caution should be taken in applying these reactions to military environments, where longer durations and higher frequency exposures could affect aircrew perception. Likewise, the health risks of vibration have primarily been associated with the lumbar spine and connected nervous system [2]. It is logical to conclude that higher magnitude lower frequency vibration could contribute to these symptoms due to the relative upper and lower torso motions and postural instability that can dynamically and repeatedly stress the spinal column. Vibration transmission to the upper torso and head dramatically decreases at frequencies beyond 10 Hz, unless there are substantial amplitudes. Humans primarily perceive higher frequency vibration at the interfaces where the body is in contact with the vibrating surface. The mechanisms by which higher frequency vibration generates spinal musculoskeletal stresses that contribute to discomfort and pain may be physiologically different than the mechanisms associated with low frequency vibration. This suggests there could be a substantial impact on the most appropriate criteria to apply for assessing discomfort and health risk in military air vehicles.

In summary, the results of the assessments on the UH-72 and HH-60M strongly suggest that operational vibration has some effect on the discomfort and pain that has been associated with the operation of these aircraft, particularly given the magnitudes of the higher frequency exposures that still result in a potential health risk according to the standards and guidelines. The higher frequency characteristics of the vibration do warrant investigation of the mechanisms by which the vibration can cause pain and injury, leading to the development of more robust discomfort and pain mitigation strategies.

6.0 RECOMMENDATIONS

1. Conduct periodic monitoring of the aircrew by occupational health specialists, particularly documenting reports of discomfort, pain, tingling, and numbness in the back, buttocks, and lower extremities. This could be accomplished using the aircrew surveys

developed for this study or some modification. (The results of the survey conducted under this study will be documented in a subsequent report.)

2. Consider adding seat pan and seat back cushion support that may improve posture and also mitigate some of the higher frequency vibration entering the occupant at interfaces, particularly for aircrew occupying the back of the aircraft. Attention should be paid to the multi-axis characteristics of the exposures.

3. If feasible, collect additional vibration data for health risk assessment using different aircrew on the same platforms to broaden the population and explore any effects on the current assessment results.

4. Leverage the results of this study to expand vibration characterization and health risk assessments to other platforms.

5. Explore possible physiological mechanisms by which higher frequency vibration and posture may contribute to pain/injury.

6. Conduct controlled testing of current aircrew seating systems for quantifying and comparing mulit-axis vibration transmission characteristics, posture influences, and for developing mitigation strategies.

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Table A-1. REVER Component Details

Component	Dimensions (L/W/H cm)	Weight (Kg)	Item Identification
Large DAUs	16.5/10.0/4.0	0.910 w/cables	EME S/N 96-59 ID 54
			EME S/N 98-11 ID 53
Small DAU	9.5/7.0/2.8	0.370 w/cables	EME S/N 04-22 ID 55
Large Batteries	10.0/7.0/3.5	0.645	BAT 2013 III
			BAT 2013 IV
			BAT 2013 VII
			BAT 2013 VIII
Small Batteries	9.0/5.0/3.5	0.395	BAT 2013 I
			BAT 2013 II
			BAT 2013 V
			BAT 2013 VI
Accelerometer Packs (Entran EGAX-25)	1.9 (diameter) 0.86 (thickness)	0.005 (0.060 w/ cable)	Pack L
			Pack M
			Pack D
			Pack N (Spare)
			Pack P (Spare)
Accelerometer Pad (Entran EGAX-25) (Ride Quality Meter, RQM)	20.0 (diameter)	0.340 w/ cables	RQM 1 (Pack S)
			RQM 2 (Pack C)
			RQM 3 (Pack W)
			RQM 4 (Pack T)
			RQM 5 (Pack K)
			RQM 6 (Pack Q)
Triggers	7.6 (length) 2.2 (diameter)	0.030 w/cable	TRIG 1
			TRIG 2
			TRIG 3
Helmet Mounts (Entran EGA-125-10D)	6.5 (one arm)	0.050 w/cables	Helmetbar 1
			Helmetbar 2
Extra Cable	183 (length)	0.100	
Total Estimated Weight w/ two batteries + cable and two acceleration pads		2.23 – 2.77	

Table A-2. Flight Test Conditions

FLIGHT TEST RECORDS			
AC/#:	LOCATION/DATE:		
PI: CP:	CC:		
Medic:	Other:		
Flight #:	Station		
CONDITION (*Multiple Test Records Desired)	ALT (ft MSL)	A/S (KCAS)	COMMENTS (Wind, Day, Night, etc.)
TASK 1024 Before Starting Through Before Leaving Helo Checks			
A. Engine Idle	0	0	
Record #:			
B. Ground Flight 100%	0	0	
Record #:			
TASK 1040 Perform VMC Takeoff			
C. Takeoff Normal		A/R	
Record #:			
D. Takeoff Vertical			
Record#:			
E. Takeoff Minimum Power			
Record#:			
TASK 1038 Perform Hovering Flight			
F. Hovering Stationary IGE*	3	0	
Record#:			
G. Hovering Taxi IGE*	3	0	
Record #:			
H. Hover OGE*	50<10K	0	
Record #:			
I. Transverse Flow*			
Record #:			
J. Landing	0	0	
Record #:			
TASK 1052 Perform VMC Flight Maneuvers			
K. Climb	<10K	65-80	
Record #:			
L. Level Flight*	<10K	80	
Record#:			
M. Level Flight*	<10K	100	
Record#:			
N. Level Flight*	<10K	120	
Record #:			
O. Std Rate Turn	<10K	≤120	
Record #:			

FLIGHT TEST RECORDS			
AC/#:	LOCATION/DATE:		
PI: CP:	CC:		
Medic:	Other:		
Flight #:	Station		
CONDITION (*Multiple Test Records Desired)	ALT (ft MSL)	A/S (KCAS)	COMMENTS (Wind, Day, Night, etc.)
TASK 1052 Perform VMC Flight Maneuvers			
P. Steep Rate Turn	<10K	≤120	
Record#:			
Q. Descent		≤120	
Record #:			
R. AVCS Off	<10K	≤120	
Record #:			
TASK 1058 Perform VMC Approach			
S. Normal Approach to OGE Hover*	>50	≤120-0	8-10°
Record #:			
T. Steep Approach to OGE Hover*	>50	≤120-0	>10°
Record#:			
U. Normal Approach to IGE Hover*	3	≤120-0	
Record#:			
V. Steep Approach to IGE Hover*	3	≤120-0	
Record#:			
TASK 2026 Perform Terrain Flight			
W. NOE*	0-25	≤120	
Record #:			
TASK 2048 Perform Sling Load Operations (simulated)			
H. Hover OGE*	50<10K	0	
Record #:			
TASK 2060 Perform Rescue Hoist Operations (simulated)			
H. Hover OGE*	50<10K	0	
Record #:			
X.			
Y.			
Z.			
AA.			
AB.			
AC.			
AD.			

Table A-3. UH-72 and HH-60M Flight Test Condition Records

	UH-72			HH-60M		
	# of Records			# of Records		
Task/Condition	**Flt 1**	**Flt 2**	**Flt 3**	**Flt 1**	**Flt 2a**	**Flt 2b**
TASK 1024 Before Start – Before Leave Helo Checks						
Engine Idle	1	2	3	3	-	3[1]
Grd Flt 100%	1	2	3	3	-	4
TASK 1040 Perform VMC Takeoff						
TO Normal	3	2	2	2	-	1
TO Vertical	-	3	2	2	-	1
TO Min Power	-	2	2	2	-	1
TASK 1038 Perform Hovering Flight						
Hover Stat IGE	3	-	3	3	-	-
Hover Taxi IGE	2	-	-	3	3	-
Hover OGE	3	3	3	3	4	-
Trans Flow	-	4	3	2[2]	-	4
Landing	-	-	-	1	-	3
TASK 1052 Perform VMC Flight Maneuvers						
Climb	3	-	2	1	2	1
Level Flt 80 KCAS	2	4	4	5	4[3]	-
Level Flt 100 KCAS	3	4	5	3	3	3
Level Flt 120 KCAS	6	8	6	8	4	6
Std Rate Turn	4	-	4	4	3	-
Steep Rate Turn	-	4[4]	4	3	3	-
Descent	3	-	3	7	3[5]	-
AVCS Off	-	-	-	2	-	-
TASK 1058 Perform VMC Approach						
NA OGE Hover	1	1	0	2[6]	-	1
SA OGE Hover	0	0	0	1	-	1
NA IGE Hover	2	4	4	1	1	1
SA IGE Hover	0	2	0	1	-	1
TASK 1026 NOE						
NOE	-	-	-		7	

[1]HH-60M Medic has 4 records
[2]HH-60M Crew Chief has 3 records
[3]HH-60M Pilot has 5 records
[4]UH-72 Crew Chief has 3 records
[5]HH-60M Medic has 2 records
[6]HH-60M Crew Chief has 3 records

Table A-4. UH-72 Pilot Station Overall Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	17	0.594	1.077	0.548	0.064	0.177	0.289	0.345	17.960	71.841	12.592	50.367
1	80	20	0.696	1.108	0.559	0.072	0.168	0.297	0.349	17.009	68.035	12.320	49.281
2	80	11	0.716	1.123	0.553	0.067	0.151	0.285	0.329	18.437	73.748	13.829	55.317
2	80	19	0.694	1.103	0.583	0.060	0.164	0.311	0.357	15.512	62.048	11.774	47.096
2	80	20	0.630	1.045	0.567	0.068	0.177	0.303	0.357	16.383	65.532	11.765	47.062
2	80	21	0.637	1.079	0.552	0.065	0.163	0.299	0.347	16.736	66.943	12.467	49.869
3	80	41	0.733	1.217	0.506	0.067	0.160	0.278	0.328	19.405	77.619	13.968	55.871
3	80	42	0.800	1.117	0.494	0.068	0.142	0.265	0.308	21.409	85.637	15.811	63.244
3	80	43	0.794	1.119	0.499	0.071	0.153	0.275	0.322	19.904	79.617	14.436	57.744
3	80	44	0.791	1.109	0.478	0.071	0.145	0.264	0.310	21.503	86.013	15.634	62.535
MEAN			0.708	1.110	0.534	0.067	0.160	0.287	0.335	18.426	73.703	13.460	53.839
STDEV			0.073	0.045	0.036	0.004	0.012	0.016	0.018	2.089	8.354	1.504	6.015
1	100	2	0.636	1.193	0.624	0.065	0.179	0.339	0.389	13.034	52.135	9.905	39.619
1	100	3	0.674	1.209	0.668	0.073	0.208	0.366	0.427	11.219	44.875	8.237	32.947
1	100	4	0.656	1.173	0.654	0.074	0.192	0.353	0.409	12.040	48.160	8.977	35.906
2	100	7	0.720	1.221	0.638	0.072	0.191	0.346	0.402	12.511	50.043	9.280	37.118
2	100	8	0.757	1.238	0.641	0.069	0.167	0.342	0.387	12.816	51.264	10.009	40.037
2	100	9	0.740	1.251	0.631	0.068	0.176	0.336	0.385	13.266	53.066	10.096	40.383
2	100	10	0.764	1.179	0.625	0.070	0.165	0.336	0.381	13.257	53.030	10.316	41.264
3	100	2	0.940	0.969	0.542	0.084	0.118	0.278	0.313	13.903	55.612	9.408	37.631
3	100	3	0.863	1.676	0.574	0.090	0.226	0.333	0.412	13.564	54.257	8.831	35.324
3	100	4	0.752	1.595	0.601	0.084	0.234	0.350	0.429	12.264	49.055	8.149	32.597
3	100	45	0.794	0.837	0.439	0.063	0.107	0.261	0.289	13.316	53.262	9.685	38.742
3	100	46	0.798	1.440	0.603	0.085	0.203	0.347	0.411	12.443	49.773	8.868	35.471
MEAN			0.758	1.248	0.603	0.075	0.181	0.332	0.386	12.803	51.211	9.313	37.253
STDEV			0.086	0.234	0.062	0.009	0.038	0.031	0.043	0.746	2.985	0.717	2.869
1	120	29	0.654	0.787	0.686	0.080	0.211	0.385	0.447	10.096	40.386	7.522	30.088
1	120	30	0.735	0.881	0.695	0.083	0.215	0.384	0.448	10.196	40.785	7.481	29.926
1	120	31	0.654	0.742	0.675	0.074	0.173	0.376	0.420	10.630	42.520	8.493	33.972
1	120	32	1.025	0.954	0.773	0.118	0.202	0.427	0.487	8.217	32.867	6.320	25.281
1	120	33	0.935	1.023	0.771	0.113	0.214	0.437	0.500	7.846	31.384	6.002	24.007
1	120	34	0.912	1.003	0.775	0.105	0.208	0.432	0.491	8.021	32.083	6.213	24.853
2	120	22	0.731	0.992	0.721	0.090	0.240	0.402	0.477	9.290	37.161	6.599	26.395
2	120	23	0.701	0.909	0.703	0.080	0.198	0.387	0.442	10.023	40.093	7.682	30.730
2	120	24	0.707	0.967	0.706	0.081	0.209	0.395	0.454	9.596	38.385	7.270	29.082
2	120	25	0.875	1.259	0.760	0.107	0.228	0.425	0.494	8.293	33.170	6.137	24.547
2	120	43	0.916	1.218	0.724	0.103	0.192	0.398	0.454	9.457	37.827	7.281	29.126
2	120	44	0.861	1.170	0.740	0.097	0.185	0.402	0.453	9.299	37.196	7.317	29.268
2	120	45	0.976	1.295	0.810	0.115	0.233	0.449	0.518	7.456	29.825	5.585	22.341
2	120	46	0.995	1.257	0.867	0.113	0.197	0.469	0.521	6.819	27.277	5.526	22.104
3	120	8	0.810	1.157	0.574	0.082	0.155	0.311	0.357	8.448	33.794	6.116	24.463
3	120	9	0.760	1.435	0.681	0.088	0.217	0.387	0.453	9.997	39.989	7.321	29.284
3	120	10	0.801	1.294	0.726	0.096	0.241	0.418	0.492	8.566	34.265	6.195	24.778
3	120	11	0.766	1.213	0.700	0.087	0.195	0.392	0.446	9.764	39.056	7.526	30.103
3	120	47	0.769	1.107	0.524	0.068	0.151	0.318	0.358	10.589	42.358	7.326	29.304
3	120	48	1.101	1.352	0.648	0.130	0.215	0.381	0.456	10.357	41.429	7.218	28.872
MEAN			0.834	1.101	0.713	0.096	0.204	0.399	0.458	9.148	36.592	6.857	27.426
STDEV			0.128	0.194	0.076	0.017	0.025	0.038	0.044	1.115	4.460	0.800	3.200

Table A-5. UH-72 Crew Chief Station Overall Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	17	0.613	0.781	0.348	0.065	0.108	0.198	0.235	38.168	152.673	27.226	108.904
1	80	20	0.732	0.723	0.274	0.067	0.098	0.156	0.196	61.250	245.001	39.014	156.057
2	80	11	0.889	0.669	0.395	0.078	0.075	0.212	0.238	33.349	133.395	26.460	105.842
2	80	19	0.848	0.813	0.415	0.068	0.104	0.230	0.261	28.432	113.727	21.968	87.873
2	80	20	0.702	0.612	0.320	0.070	0.089	0.182	0.215	45.100	180.399	32.508	130.033
2	80	21	0.732	0.708	0.333	0.064	0.089	0.191	0.220	40.982	163.927	30.861	123.445
3	80	41	0.860	0.464	0.349	0.064	0.071	0.192	0.214	40.792	163.170	32.679	130.716
3	80	42	0.935	0.484	0.361	0.064	0.066	0.190	0.211	41.456	165.826	33.600	134.400
3	80	43	0.886	0.486	0.340	0.066	0.072	0.186	0.210	43.576	174.306	34.066	136.265
3	80	44	0.886	0.484	0.340	0.066	0.067	0.185	0.207	44.020	176.080	34.943	139.772
MEAN			0.808	0.622	0.347	0.067	0.084	0.192	0.221	41.713	166.850	31.333	125.331
STDEV			0.105	0.135	0.039	0.004	0.016	0.019	0.019	8.579	34.315	4.903	19.613
1	100	2	0.745	1.017	0.410	0.076	0.118	0.232	0.271	27.871	111.483	20.411	81.644
1	100	3	0.739	0.910	0.665	0.084	0.128	0.359	0.390	11.666	46.662	9.856	39.425
1	100	4	0.766	1.070	0.524	0.085	0.127	0.287	0.325	18.170	72.682	14.160	56.640
2	100	7	0.869	0.772	0.437	0.083	0.104	0.250	0.283	24.071	96.285	18.745	74.982
2	100	8	0.934	0.797	0.440	0.084	0.089	0.249	0.277	24.239	96.955	19.529	78.118
2	100	9	0.932	0.817	0.437	0.084	0.094	0.249	0.279	24.133	96.532	19.223	76.894
2	100	10	0.993	0.782	0.571	0.083	0.089	0.314	0.337	15.183	60.733	13.194	52.774
3	100	2	0.940	0.969	0.542	0.084	0.118	0.278	0.313	19.378	77.512	15.262	61.050
3	100	3	0.984	0.944	0.510	0.087	0.123	0.269	0.308	20.762	83.049	15.824	63.295
3	100	4	0.856	0.927	0.567	0.090	0.128	0.299	0.337	16.809	67.238	13.208	52.833
3	100	45	0.794	0.837	0.439	0.063	0.107	0.261	0.289	22.018	88.073	17.966	71.864
3	100	46	0.776	0.834	0.459	0.065	0.110	0.271	0.300	20.436	81.745	16.703	66.811
MEAN			0.861	0.890	0.500	0.081	0.111	0.276	0.309	20.395	81.579	16.174	64.694
STDEV			0.095	0.098	0.076	0.008	0.015	0.035	0.034	4.504	18.015	3.180	12.719
1	120	29	0.851	1.125	0.484	0.090	0.151	0.302	0.350	16.409	65.638	12.264	49.058
1	120	30	0.846	1.163	0.476	0.079	0.159	0.290	0.340	17.879	71.517	13.005	52.019
1	120	31	0.843	1.093	0.459	0.075	0.136	0.282	0.322	18.838	75.353	14.445	57.781
1	120	32	0.842	1.226	0.515	0.080	0.153	0.305	0.350	16.138	64.550	12.238	48.950
1	120	33	0.871	1.303	0.492	0.083	0.170	0.308	0.362	15.765	63.060	11.465	45.859
1	120	34	0.872	1.294	0.497	0.079	0.162	0.309	0.358	15.664	62.655	11.691	46.763
2	120	22	0.819	1.228	0.545	0.086	0.171	0.314	0.367	15.248	60.993	11.124	44.498
2	120	23	0.836	1.215	0.516	0.078	0.157	0.290	0.340	17.778	71.112	13.014	52.054
2	120	24	0.730	1.167	0.495	0.071	0.157	0.290	0.338	17.829	71.315	13.160	52.639
2	120	25	0.850	1.344	0.538	0.086	0.167	0.309	0.362	15.663	62.653	11.455	45.819
2	120	43	0.719	1.060	0.469	0.061	0.137	0.286	0.322	18.377	73.509	14.423	57.692
2	120	44	0.831	1.200	0.466	0.064	0.140	0.252	0.296	23.558	94.231	17.151	68.602
2	120	45	0.708	1.275	0.541	0.068	0.168	0.319	0.367	14.765	59.061	11.142	44.570
2	120	46	0.680	1.317	0.518	0.065	0.159	0.303	0.349	16.289	65.158	12.331	49.325
3	120	8	0.810	1.157	0.574	0.082	0.155	0.311	0.357	15.548	62.193	11.791	47.165
3	120	9	0.828	1.072	0.559	0.077	0.138	0.309	0.347	15.723	62.892	12.477	49.909
3	120	10	0.859	1.124	0.614	0.086	0.158	0.337	0.382	13.230	52.919	10.297	41.189
3	120	11	0.827	1.148	0.588	0.077	0.142	0.315	0.354	15.121	60.486	11.987	47.947
3	120	47	0.769	1.107	0.524	0.068	0.151	0.318	0.358	14.842	59.367	11.685	46.740
3	120	48	0.749	1.155	0.500	0.066	0.153	0.307	0.349	15.951	63.802	12.315	49.261
MEAN			0.807	1.189	0.519	0.076	0.154	0.303	0.348	16.531	66.123	12.473	49.892
STDEV			0.059	0.084	0.042	0.008	0.011	0.018	0.019	2.151	8.606	1.506	6.023

Table A-6. UH-72 Medic Station Overall Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	17	0.832	2.525	0.645	0.099	0.299	0.361	0.479	11.532	46.129	6.540	26.160
1	80	20	0.830	2.635	0.670	0.097	0.316	0.380	0.504	10.383	41.533	5.909	23.638
2	80	11	0.928	2.380	0.709	0.109	0.276	0.406	0.502	9.113	36.453	5.942	23.768
2	80	19	0.804	2.409	0.669	0.103	0.301	0.397	0.509	9.527	38.107	5.795	23.181
2	80	20	0.804	2.464	0.762	0.104	0.319	0.427	0.543	8.231	32.923	5.086	20.344
2	80	21	0.795	2.469	0.741	0.097	0.300	0.426	0.530	8.260	33.041	5.332	21.330
3	80	42	0.792	2.484	0.775	0.094	0.287	0.432	0.528	8.026	32.104	5.390	21.560
3	80	43	0.773	2.395	0.772	0.092	0.278	0.428	0.519	8.170	32.679	5.567	22.267
3	80	44	0.784	2.445	0.786	0.094	0.287	0.440	0.533	7.753	31.012	5.273	21.091
3	80	45	0.786	2.419	0.778	0.096	0.287	0.434	0.529	7.979	31.916	5.364	21.457
MEAN			0.813	2.463	0.731	0.098	0.295	0.413	0.518	8.897	35.590	5.620	22.479
STDEV			0.045	0.075	0.053	0.005	0.015	0.026	0.019	1.242	4.968	0.431	1.725
1	100	2	0.906	2.953	0.906	0.105	0.348	0.373	0.521	10.800	43.201	5.534	22.135
1	100	3	0.955	3.012	0.955	0.115	0.369	0.353	0.523	12.029	48.117	5.476	21.905
1	100	4	0.932	3.076	0.932	0.117	0.373	0.372	0.540	10.843	43.374	5.146	20.583
2	100	7	0.906	2.534	0.906	0.115	0.309	0.426	0.538	8.279	33.114	5.179	20.716
2	100	8	0.929	2.620	0.929	0.108	0.303	0.422	0.531	8.406	33.625	5.315	21.262
2	100	9	0.894	2.577	0.894	0.105	0.298	0.424	0.529	8.340	33.359	5.361	21.445
2	100	10	0.868	2.555	0.868	0.104	0.297	0.430	0.533	8.120	32.482	5.284	21.136
3	100	3	0.882	2.342	0.882	0.108	0.287	0.379	0.487	10.434	41.736	6.313	25.250
3	100	4	0.905	2.376	0.905	0.111	0.298	0.361	0.481	11.509	46.038	6.481	25.924
3	100	5	0.883	2.345	0.883	0.122	0.319	0.432	0.551	8.020	32.081	4.938	19.753
3	100	46	0.941	2.940	0.941	0.105	0.348	0.465	0.590	6.934	27.738	4.307	17.228
3	100	47	0.912	2.938	0.912	0.106	0.350	0.475	0.599	6.652	26.608	4.178	16.714
MEAN			0.910	2.689	0.910	0.110	0.325	0.409	0.535	9.197	36.789	5.293	21.171
STDEV			0.026	0.277	0.026	0.006	0.031	0.041	0.034	1.822	7.289	0.669	2.676
1	120	29	0.622	2.564	0.664	0.091	0.352	0.445	0.575	7.570	30.280	4.542	18.167
1	120	30	0.617	2.510	0.661	0.095	0.332	0.427	0.549	8.218	32.870	4.969	19.876
1	120	31	0.634	2.580	0.639	0.087	0.326	0.416	0.535	8.683	34.731	5.231	20.926
1	120	32	0.638	2.572	0.626	0.102	0.350	0.424	0.559	8.351	33.404	4.796	19.185
1	120	33	0.681	2.663	0.665	0.097	0.358	0.462	0.592	7.041	28.164	4.278	17.110
1	120	34	0.666	2.643	0.635	0.111	0.371	0.420	0.571	8.504	34.015	4.601	18.404
2	120	22	0.575	2.204	0.786	0.102	0.339	0.479	0.595	6.551	26.205	4.237	16.950
2	120	23	0.541	2.142	0.812	0.089	0.299	0.513	0.601	5.695	22.779	4.157	16.626
2	120	24	0.531	2.171	0.800	0.093	0.308	0.491	0.587	6.212	24.849	4.346	17.385
2	120	25	0.700	2.324	0.802	0.101	0.325	0.502	0.606	5.963	23.852	4.079	16.315
2	120	43	0.691	2.931	0.799	0.089	0.365	0.471	0.602	6.769	27.076	4.138	16.554
2	120	44	0.684	2.861	0.637	0.083	0.346	0.399	0.535	9.402	37.609	5.241	20.964
2	120	45	0.587	2.536	0.959	0.087	0.326	0.563	0.656	4.740	18.959	3.486	13.945
2	120	46	0.569	2.484	0.951	0.075	0.311	0.568	0.651	4.657	18.628	3.535	14.140
3	120	9	0.569	1.992	0.735	0.100	0.274	0.465	0.549	6.935	27.739	4.981	19.925
3	120	10	0.565	2.015	0.698	0.093	0.272	0.442	0.527	7.691	30.762	5.404	21.617
3	120	11	0.577	2.034	0.717	0.103	0.294	0.458	0.554	7.147	28.590	4.887	19.546
3	120	12	0.535	2.051	0.743	0.083	0.267	0.455	0.534	7.253	29.013	5.260	21.040
3	120	48	0.666	2.468	0.884	0.093	0.322	0.527	0.625	5.394	21.576	3.840	15.360
3	120	49	0.652	2.563	0.890	0.090	0.322	0.532	0.628	5.301	21.203	3.801	15.205
MEAN			0.615	2.415	0.755	0.093	0.323	0.473	0.582	6.904	27.615	4.491	17.962
STDEV			0.056	0.282	0.106	0.008	0.030	0.049	0.039	1.349	5.398	0.591	2.363

Table A-7. HH-60M Pilot Station Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	13	0.943	1.413	0.508	0.106	0.244	0.285	0.390	18.426	73.705	9.865	39.460
1	80	14	1.029	1.477	0.522	0.141	0.268	0.290	0.419	17.839	71.358	8.529	34.116
1	80	15	0.823	1.434	0.539	0.101	0.247	0.311	0.409	15.555	62.218	8.966	35.864
1	80	16	0.893	1.467	0.496	0.091	0.249	0.266	0.376	21.158	84.634	10.613	42.453
1	80	17	0.938	1.513	0.514	0.133	0.273	0.291	0.421	17.689	70.754	8.482	33.927
2a	80	20	0.959	1.393	0.611	0.111	0.235	0.302	0.398	16.417	65.666	9.459	37.836
2a	80	21	0.963	1.431	0.607	0.111	0.244	0.307	0.407	15.956	63.823	9.047	36.187
2a	80	22	0.952	1.385	0.601	0.107	0.235	0.318	0.409	14.873	59.491	8.952	35.806
2a	80	23	0.900	1.443	0.553	0.100	0.245	0.322	0.417	14.453	57.814	8.624	34.495
2a	80	24	0.891	1.425	0.587	0.108	0.244	0.352	0.442	12.082	48.327	7.668	30.670
	MEAN		0.929	1.438	0.554	0.111	0.248	0.304	0.409	16.445	65.779	9.020	36.081
	STDEV		0.056	0.039	0.044	0.015	0.013	0.024	0.018	2.498	9.990	0.814	3.258
1	100	10	0.970	1.298	0.561	0.145	0.230	0.327	0.426	14.005	56.020	8.277	33.109
1	100	11	0.999	1.232	0.599	0.145	0.230	0.327	0.443	13.059	52.235	7.660	30.640
1	100	12	0.962	1.208	0.558	0.135	0.231	0.328	0.423	13.939	55.755	8.368	33.473
2a	100	25	1.057	1.211	0.670	0.126	0.212	0.377	0.450	10.580	42.319	7.399	29.598
2a	100	26	1.070	1.179	0.675	0.123	0.201	0.376	0.443	10.632	42.527	7.630	30.522
2a	100	27	1.045	1.203	0.679	0.127	0.210	0.380	0.452	10.410	41.640	7.337	29.349
2b	100	60	1.108	1.170	0.776	0.137	0.199	0.444	0.506	7.605	30.419	5.864	23.455
2b	100	61	1.080	1.160	0.728	0.133	0.199	0.432	0.494	8.042	32.167	6.155	24.619
2b	100	62	1.096	1.257	0.725	0.151	0.222	0.418	0.497	8.573	34.291	6.080	24.319
	MEAN		1.043	1.213	0.663	0.136	0.215	0.379	0.459	10.760	43.041	7.197	28.787
	STDEV		0.054	0.044	0.076	0.010	0.014	0.045	0.031	2.455	9.820	0.943	3.772
1	120	7	1.219	1.020	0.613	0.215	0.216	0.316	0.439	15.048	60.191	7.786	31.143
1	120	8	1.287	0.993	0.628	0.227	0.214	0.329	0.454	13.822	55.289	7.284	29.137
1	120	9	1.441	0.941	0.717	0.257	0.204	0.410	0.525	8.935	35.740	5.445	21.778
1	120	18	1.296	1.099	0.644	0.210	0.208	0.345	0.454	12.632	50.528	7.283	29.133
1	120	52	1.231	0.810	0.622	0.193	0.164	0.397	0.471	9.515	38.061	6.760	27.041
1	120	53	1.225	0.860	0.669	0.198	0.161	0.433	0.502	8.018	32.072	5.942	23.768
1	120	54	1.203	0.868	0.702	0.205	0.171	0.453	0.526	7.314	29.256	5.427	21.707
1	120	55	1.186	0.871	0.726	0.211	0.167	0.478	0.549	6.565	26.259	4.986	19.943
2a	120	28	1.387	0.972	0.786	0.223	0.189	0.456	0.541	7.215	28.859	5.119	20.477
2a	120	29	1.393	0.924	0.781	0.211	0.178	0.458	0.535	7.149	28.595	5.248	20.992
2a	120	30	1.375	0.952	0.761	0.205	0.175	0.435	0.512	7.929	31.714	5.732	22.927
2a	120	31	1.407	0.955	0.793	0.215	0.183	0.470	0.548	6.803	27.211	4.994	19.978
2b	120	63	1.410	1.032	0.793	0.201	0.178	0.452	0.526	7.328	29.313	5.423	21.693
2b	120	64	1.480	1.092	0.832	0.204	0.180	0.468	0.542	6.836	27.345	5.115	20.461
2b	120	65	1.460	1.070	0.837	0.203	0.181	0.468	0.542	6.842	27.368	5.116	20.465
2b	120	66	1.455	1.061	0.822	0.197	0.174	0.475	0.543	6.661	26.645	5.095	20.381
2b	120	67	1.457	1.011	0.767	0.196	0.175	0.440	0.513	7.739	30.956	5.706	22.825
2b	120	68	1.482	1.070	0.810	0.220	0.193	0.478	0.561	6.567	26.266	4.774	19.096
	MEAN		1.355	0.978	0.739	0.211	0.184	0.431	0.516	8.495	33.982	5.735	22.941
	STDEV		0.106	0.087	0.076	0.015	0.017	0.052	0.037	2.614	10.456	0.914	3.656
1	AVCS OFF	38	1.418	0.884	1.182	0.232	0.155	0.807	0.854	2.303	9.212	2.058	8.232
1	AVCS OFF	39	1.399	0.813	1.218	0.219	0.153	0.835	0.877	2.151	8.604	1.951	7.805
	MEAN		1.409	0.848	1.200	0.225	0.154	0.821	0.865	2.227	8.908	2.005	8.018
	STDEV		0.013	0.050	0.025	0.009	0.001	0.020	0.016	0.108	0.430	0.075	0.302
2a	NOE	7	1.806	1.055	0.708	0.151	0.298	0.352	0.485	12.091	48.363	6.368	25.471
2a	NOE	8	2.013	1.133	0.725	0.169	0.327	0.350	0.508	12.256	49.025	5.812	23.248
2a	NOE	9	1.847	1.061	0.784	0.160	0.309	0.415	0.542	8.710	34.839	5.113	20.453
2a	NOE	10	1.673	0.996	0.622	0.135	0.280	0.279	0.418	19.260	77.039	8.588	34.351
2a	NOE	11	1.657	0.891	0.636	0.127	0.279	0.310	0.436	15.643	62.572	7.908	31.632
2a	NOE	12	2.084	0.986	0.745	0.125	0.344	0.379	0.527	10.445	41.779	5.398	21.593
2a	NOE	13	2.012	1.078	0.709	0.160	0.333	0.360	0.516	11.570	46.279	5.642	22.568
	MEAN		1.870	1.029	0.704	0.147	0.310	0.349	0.490	12.853	51.414	6.404	25.617
	STDEV		0.171	0.079	0.057	0.018	0.026	0.044	0.047	3.521	14.084	1.332	5.327

Table A-8. HH-60M Crew Chief Station Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	12	0.479	0.819	0.757	0.076	0.080	0.287	0.308	18.150	72.598	15.827	63.309
1	80	13	0.652	0.875	0.672	0.100	0.114	0.326	0.359	14.150	56.602	11623	46.494
1	80	14	0.458	0.760	0.692	0.071	0.096	0.273	0.298	20.133	80.531	16.908	67.631
1	80	15	0.450	0.744	0.814	0.063	0.074	0.293	0.309	17.425	69.698	15.683	62.730
1	80	16	0.539	0.837	0.834	0.081	0.118	0.340	0.369	12.962	51848	11.000	43.998
2a	80	20	0.510	0.692	0.878	0.065	0.093	0.323	0.342	14.406	57.623	12.805	51221
2a	80	21	0.483	0.751	0.889	0.062	0.091	0.346	0.364	12.499	49.998	11.346	45.385
2a	80	22	0.464	0.598	1027	0.061	0.092	0.355	0.371	11933	47.734	10.879	43.516
2a	80	23	0.487	0.584	1056	0.065	0.096	0.373	0.390	10.809	43.238	9.850	39.399
MEAN			0.503	0.740	0.847	0.072	0.095	0.324	0.346	14.719	58.874	12.880	51.520
STDEV			0.062	0.101	0.134	0.013	0.014	0.033	0.033	3.160	12.639	2.584	10.337
1	100	9	0.690	0.788	0.525	0.106	0.088	0.268	0.301	20.876	83.502	16.505	66.021
1	100	10	0.695	0.830	0.566	0.110	0.084	0.308	0.337	15.849	63.395	13.186	52.746
1	100	11	0.681	0.715	0.526	0.107	0.097	0.290	0.324	17.850	71399	14.322	57.287
2a	100	24	0.638	0.697	0.687	0.083	0.083	0.377	0.394	10.581	42.323	9.650	38.601
2a	100	25	0.648	0.709	0.663	0.098	0.093	0.376	0.399	10.618	42.472	9.413	37.651
2a	100	26	0.583	0.642	0.668	0.082	0.084	0.378	0.396	10.521	42.085	9.590	38.358
2b	100	59	0.919	0.731	1000	0.142	0.089	0.584	0.607	4.402	17.607	4.066	16.264
2b	100	60	0.942	0.705	0.980	0.146	0.087	0.632	0.654	3.760	15.042	3.507	14.027
2b	100	61	0.946	0.718	0.987	0.147	0.086	0.639	0.661	3.676	14.705	3.431	13.725
MEAN			0.749	0.726	0.734	0.113	0.088	0.428	0.453	10.904	43.615	9.297	37.187
STDEV			0.144	0.054	0.201	0.026	0.004	0.149	0.146	6.305	25.219	4.846	19.383
1	120	6	0.963	0.787	0.582	0.153	0.096	0.317	0.365	14.949	59.796	11.269	45.075
1	120	7	1079	0.793	0.597	0.173	0.107	0.342	0.399	12.788	51.150	9.440	37.758
1	120	8	1306	0.843	0.781	0.212	0.089	0.509	0.558	5.798	23.190	4.817	19.267
1	120	17	0.965	0.872	0.760	0.147	0.103	0.410	0.448	8.902	35.608	7.465	29.860
1	120	52	1038	0.681	0.934	0.166	0.090	0.627	0.655	3.817	15.267	3.499	13.996
1	120	53	1179	0.647	1076	0.191	0.094	0.752	0.782	2.652	10.608	2.456	9.823
1	120	54	1185	0.665	1122	0.192	0.085	0.786	0.814	2.426	9.706	2.264	9.057
1	120	55	1242	0.903	1222	0.200	0.104	0.860	0.889	2.029	8.114	1899	7.594
2a	120	27	1059	0.662	0.844	0.162	0.105	0.520	0.554	5.558	22.230	4.880	19.520
2a	120	28	1110	0.745	0.837	0.170	0.115	0.535	0.572	5.250	20.999	4.577	18.310
2a	120	29	1049	0.690	0.777	0.159	0.095	0.475	0.510	6.636	26.544	5.762	23.047
2a	120	30	1067	0.689	0.830	0.159	0.095	0.516	0.548	5.639	22.557	4.992	19.967
2b	120	62	1352	0.810	1248	0.216	0.096	0.812	0.845	2.276	9.105	2.098	8.394
2b	120	63	1381	0.796	1226	0.218	0.100	0.793	0.829	2.384	9.536	2.184	8.736
2b	120	64	1369	0.768	1194	0.216	0.094	0.767	0.803	2.547	10.189	2.327	9.310
2b	120	65	1264	0.802	1265	0.200	0.095	0.839	0.868	2.129	8.515	1990	7.961
2b	120	66	1121	0.708	1025	0.176	0.088	0.670	0.698	3.342	13.368	3.076	12.305
2b	120	67	1271	0.757	1097	0.203	0.103	0.732	0.766	2.800	11201	2.554	10.216
MEAN			1.167	0.757	0.968	0.184	0.098	0.626	0.661	5.107	20.427	4.308	17.233
STDEV			0.136	0.076	0.225	0.024	0.008	0.176	0.171	3.736	14.942	2.715	10.861
1	AVCS OFF	37	1209	0.802	1269	0.191	0.108	0.886	0.913	1910	7.638	1799	7.196
1	AVCS OFF	38	1221	0.783	1236	0.194	0.122	0.863	0.893	2.014	8.056	1881	7.526
MEAN			1.215	0.793	1.253	0.193	0.115	0.875	0.903	1.962	7.847	1.840	7.361
STDEV			0.009	0.014	0.023	0.002	0.010	0.016	0.014	0.074	0.295	0.058	0.233
2a	NOE	7	0.750	0.743	0.770	0.105	0.105	0.300	0.334	16.705	66.819	13.430	53.721
2a	NOE	8	0.784	0.818	0.833	0.123	0.124	0.351	0.392	12.187	48.749	9.759	39.037
2a	NOE	9	0.721	0.723	0.767	0.101	0.125	0.311	0.350	15.477	61909	12.229	48.917
2a	NOE	10	0.777	0.649	0.720	0.089	0.094	0.303	0.330	16.329	65.316	13.789	55.156
2a	NOE	11	0.751	0.596	0.749	0.078	0.089	0.297	0.319	17.054	68.216	14.722	58.886
2a	NOE	12	0.877	0.670	0.823	0.091	0.122	0.319	0.354	14.708	58.832	11992	47.969
2a	NOE	13	0.801	0.727	0.817	0.113	0.127	0.336	0.377	13.270	53.080	10.567	42.267
MEAN			0.780	0.704	0.783	0.100	0.112	0.317	0.351	15.104	60.417	12.356	49.422
STDEV			0.050	0.072	0.042	0.015	0.016	0.020	0.026	1.827	7.309	1.775	7.099

Table A-9. HH-60M Medic Station Unweighted and Weighted Seat Pan Accelerations, *pVTVs*, and Allowable Exposure Durations to Potential Health Risks (Lower HGCZ Boundary) and Health Risks Likely (Upper HGCZ Boundary)

FLIGHT #	AIRSPEED (KCAS)	RECORD #	PANX	PANY	PANZ	WT PANX	WT PANY	WT PANZ	pVTV	POTENTIAL HLTH RISKS PANZ	HLTH RISKS LIKELY WT PANZ	POTENTIAL HLTH RISKS PAN pVTV	HLTH RISKS LIKELY PAN pVTV
			ACCELERATION (ms^{-2} rms)							EXPOSURE DURATION (Hours)			
1	80	13	0.713	0.458	0.836	0.109	0.065	0.562	0.576	4.750	19.001	4.520	18.078
1	80	14	0.797	0.479	0.823	0.130	0.079	0.579	0.599	4.475	17.902	4.187	16.748
1	80	15	0.877	0.473	0.920	0.141	0.067	0.650	0.668	3.552	14.209	3.358	13.431
1	80	16	0.730	0.441	0.851	0.109	0.054	0.575	0.588	4.532	18.127	4.338	17.353
1	80	17	0.715	0.428	0.806	0.117	0.086	0.544	0.563	5.073	20.290	4.734	18.935
2a	80	20	0.756	0.522	0.876	0.115	0.064	0.606	0.620	4.081	16.325	3.898	15.593
2a	80	21	0.789	0.496	0.912	0.118	0.058	0.630	0.644	3.773	15.094	3.617	14.468
2a	80	22	0.803	0.380	0.918	0.121	0.057	0.637	0.651	3.699	14.797	3.543	14.174
2a	80	23	0.854	0.361	0.975	0.132	0.063	0.681	0.696	3.237	12.949	3.095	12.379
MEAN			0.782	0.449	0.880	0.121	0.066	0.607	0.623	4.130	16.522	3.921	15.684
STDEV			0.059	0.053	0.056	0.011	0.010	0.045	0.045	0.612	2.449	0.559	2.236
1	100	10	0.836	0.468	0.874	0.133	0.071	0.611	0.629	4.021	16.083	3.790	15.158
1	100	11	0.901	0.490	0.910	0.146	0.069	0.644	0.664	3.613	14.451	3.400	13.598
1	100	12	0.980	0.476	0.980	0.157	0.080	0.696	0.718	3.094	12.376	2.908	11.630
2a	100	24	1067	0.506	1136	0.171	0.061	0.819	0.839	2.234	8.936	2.130	8.519
2a	100	25	1080	0.526	1145	0.172	0.058	0.828	0.848	2.187	8.750	2.087	8.346
2a	100	26	1058	0.501	1102	0.170	0.065	0.794	0.815	2.378	9.512	2.260	9.039
2b	100	58	1487	0.537	1427	0.239	0.065	1022	1051	1437	5.747	1357	5.428
2b	100	59	1465	0.586	1462	0.236	0.072	1056	1085	1344	5.377	1274	5.098
2b	100	60	1418	0.592	1387	0.231	0.074	1000	1029	1501	6.002	1417	5.670
MEAN			1.143	0.520	1.158	0.184	0.068	0.830	0.853	2.423	9.693	2.291	9.165
STDEV			0.248	0.045	0.222	0.041	0.007	0.165	0.169	0.968	3.873	0.908	3.631
1	120	7	0.931	0.460	0.869	0.150	0.091	0.587	0.613	4.349	17.398	3.993	15.974
1	120	8	0.985	0.466	0.929	0.162	0.097	0.629	0.657	3.786	15.145	3.474	13.895
1	120	9	1405	0.505	1258	0.233	0.089	0.891	0.925	1890	7.560	1753	7.012
1	120	18	1190	0.528	1089	0.192	0.088	0.751	0.780	2.660	10.640	2.465	9.860
1	120	52	1440	0.426	1379	0.233	0.080	0.987	1017	1540	6.162	1450	5.800
1	120	53	1668	0.453	1548	0.273	0.081	1121	1156	1194	4.777	1122	4.488
1	120	54	1675	0.455	1559	0.274	0.077	1128	1163	1179	4.717	1108	4.433
1	120	55	1774	0.479	1651	0.292	0.085	1194	1232	1053	4.211	0.989	3.955
2a	120	27	1461	0.486	1322	0.237	0.083	0.937	0.970	1708	6.834	1594	6.376
2a	120	28	1469	0.493	1347	0.239	0.087	0.963	0.996	1618	6.470	1512	6.049
2a	120	29	1351	0.469	1255	0.218	0.076	0.893	0.922	1881	7.523	1763	7.051
2a	120	30	1443	0.472	1307	0.234	0.080	0.929	0.962	1737	6.948	1622	6.488
2b	120	61	1713	0.602	1558	0.277	0.083	1101	1138	1238	4.952	1158	4.632
2b	120	62	1636	0.591	1512	0.263	0.080	1075	1110	1298	5.190	1218	4.873
2b	120	63	1623	0.582	1513	0.260	0.076	1075	1108	1299	5.195	1221	4.885
2b	120	64	1568	0.567	1516	0.251	0.078	1079	1111	1288	5.152	1216	4.865
2b	120	65	1557	0.526	1409	0.250	0.080	0.998	1032	1505	6.019	1407	5.630
2b	120	66	1720	0.536	1543	0.278	0.090	1097	1135	1247	4.987	1164	4.658
MEAN			1.478	0.505	1.365	0.240	0.083	0.969	1.002	1.804	7.216	1.679	6.718
STDEV			0.241	0.053	0.221	0.039	0.006	0.170	0.173	0.911	3.643	0.828	3.312
1	AVCS OFF	38	1398	0.439	1554	0.231	0.074	1123	1149	1188	4.754	1135	4.542
1	AVCS OFF	39	1396	0.411	1456	0.230	0.084	1052	1080	1355	5.421	1286	5.143
MEAN			1.397	0.425	1.505	0.230	0.079	1.088	1.115	1.272	5.087	1.211	4.842
STDEV			0.001	0.020	0.069	0.001	0.007	0.051	0.049	0.118	0.472	0.106	0.425
2a	NOE	7	0.548	0.879	0.977	0.135	0.074	0.670	0.687	3.345	13.379	3.178	12.711
2a	NOE	8	0.524	0.887	0.989	0.136	0.093	0.671	0.691	3.331	13.325	3.142	12.567
2a	NOE	9	0.578	0.858	1002	0.134	0.109	0.678	0.699	3.265	13.061	3.066	12.265
2a	NOE	10	0.552	0.752	0.827	0.117	0.070	0.571	0.587	4.594	18.377	4.348	17.391
2a	NOE	11	0.587	0.771	0.945	0.118	0.068	0.647	0.661	3.581	14.323	3.429	13.716
2a	NOE	12	0.628	0.786	1033	0.116	0.085	0.709	0.723	2.984	11.934	2.866	11.463
2a	NOE	13	0.501	0.835	1055	0.129	0.091	0.720	0.737	2.892	11.569	2.760	11.039
MEAN			0.560	0.824	0.975	0.126	0.084	0.667	0.684	3.427	13.710	3.255	13.022
STDEV			0.042	0.054	0.075	0.009	0.015	0.049	0.049	0.564	2.257	0.528	2.114

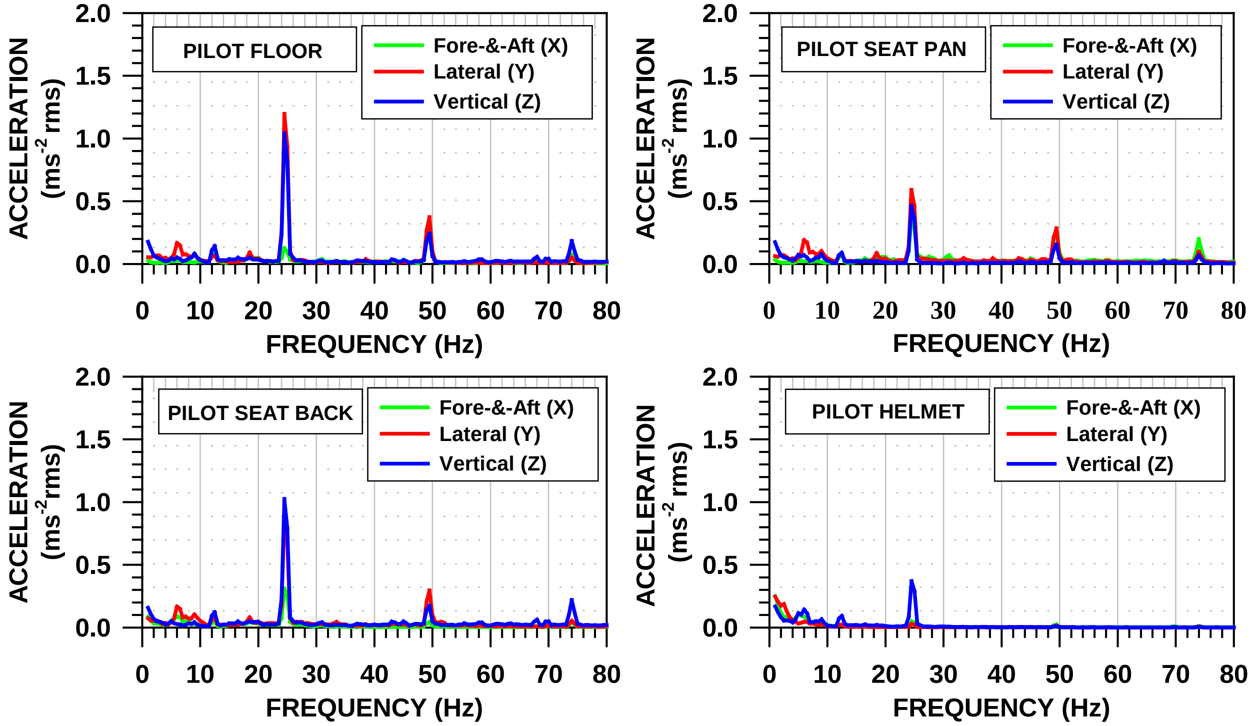

Figure A-1. UH-72 Pilot Station RMS Acceleration Spectra for Flight 2, Level Flight, 120 KCAS

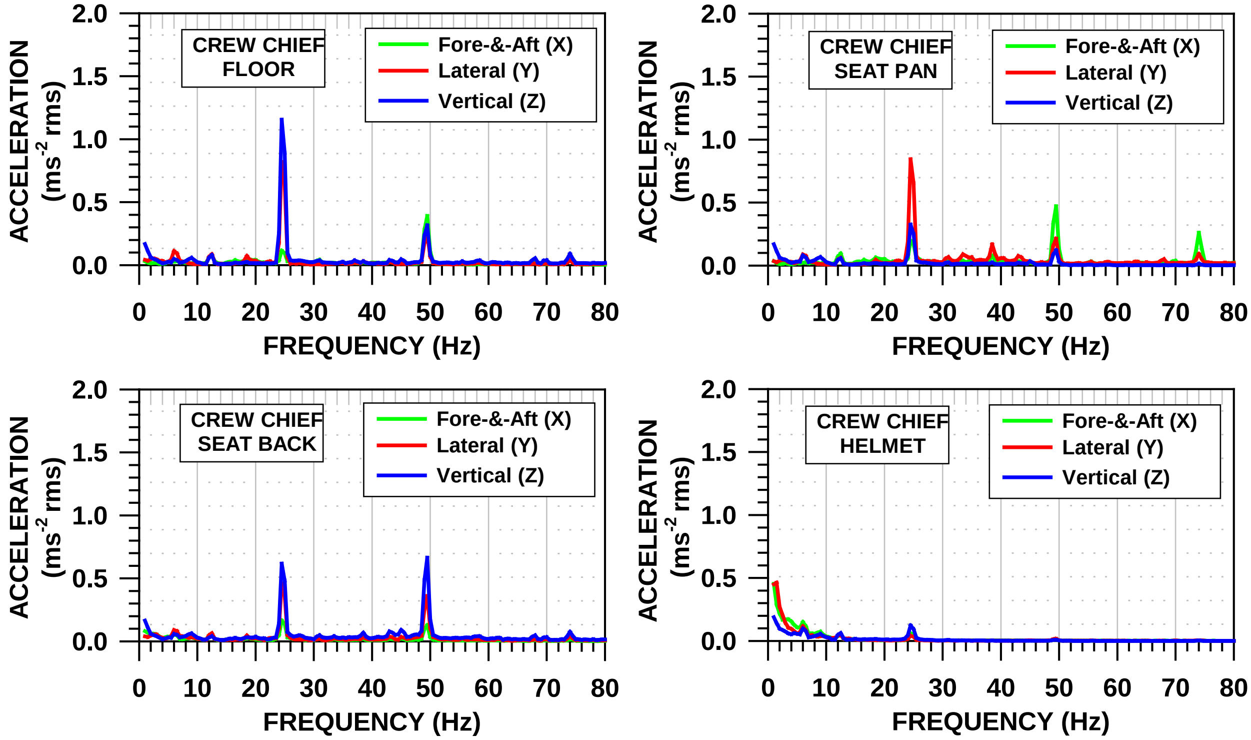

Figure A-2. UH-72 Crew Chief Station RMS Acceleration Spectra for Flight 2, Level Flight, 120 KCAS

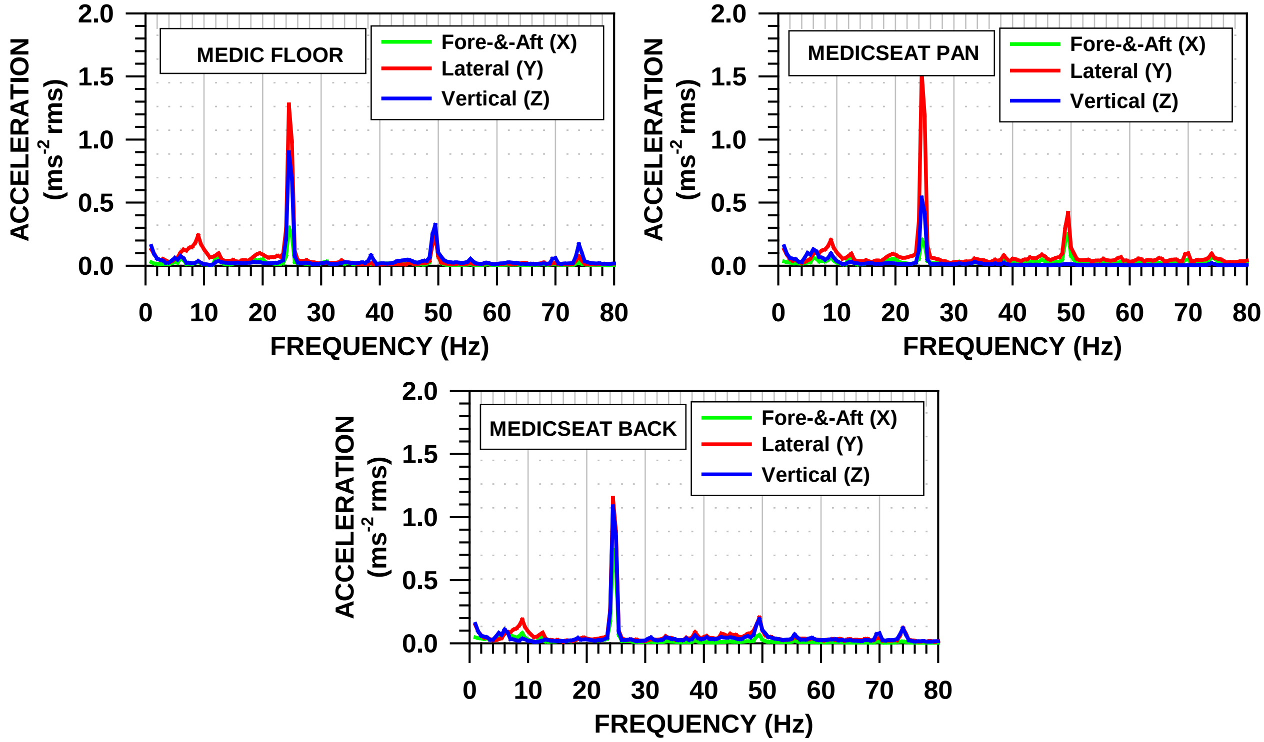

Figure A-3. UH-72 Medic Station RMS Acceleration Spectra for Flight 2, Level Flight, 120 KCAS

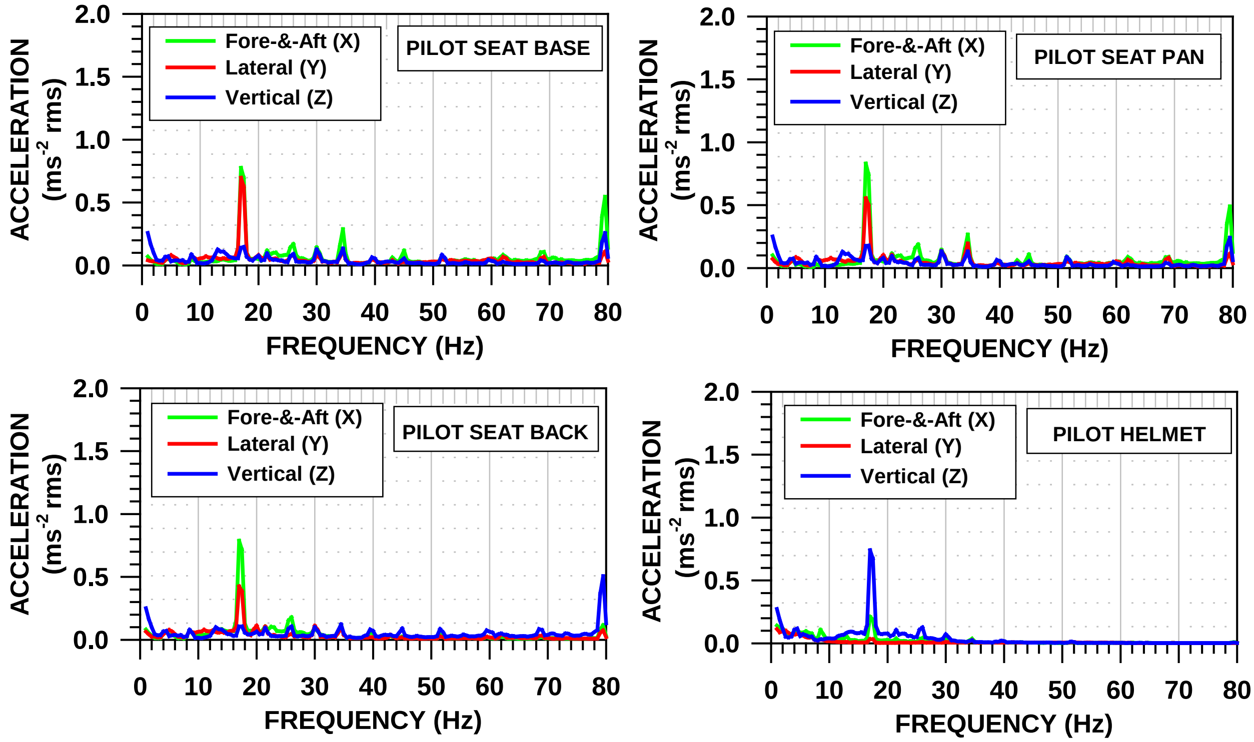

Figure A-4. HH-60M Pilot Station RMS Acceleration Spectra for Flight 1, Level Flight, 120 KCAS

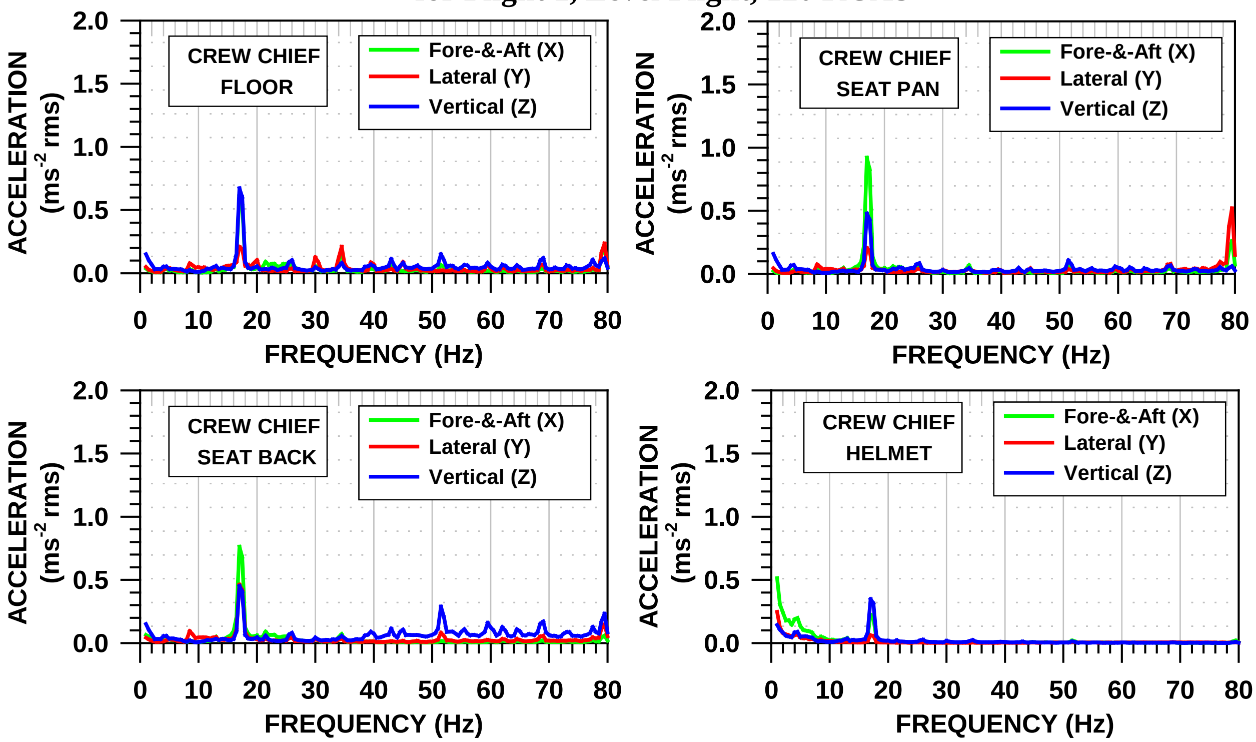

Figure A-5. HH-60M Crew Chief Station RMS Acceleration Spectra for Flight 1, Level Flight, 120 KCAS

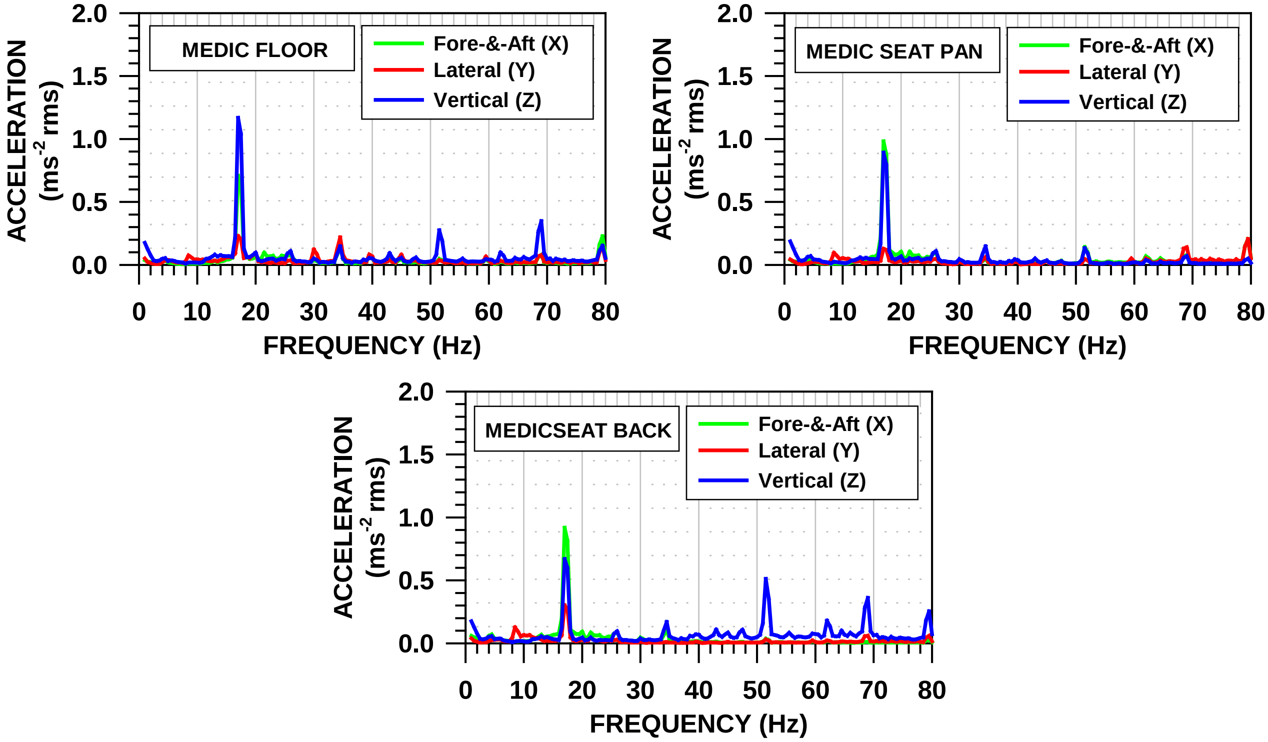

Figure A-6. HH-60M Medic Station RMS Acceleration Spectra for Flight 1, Level Flight, 120 KCAS

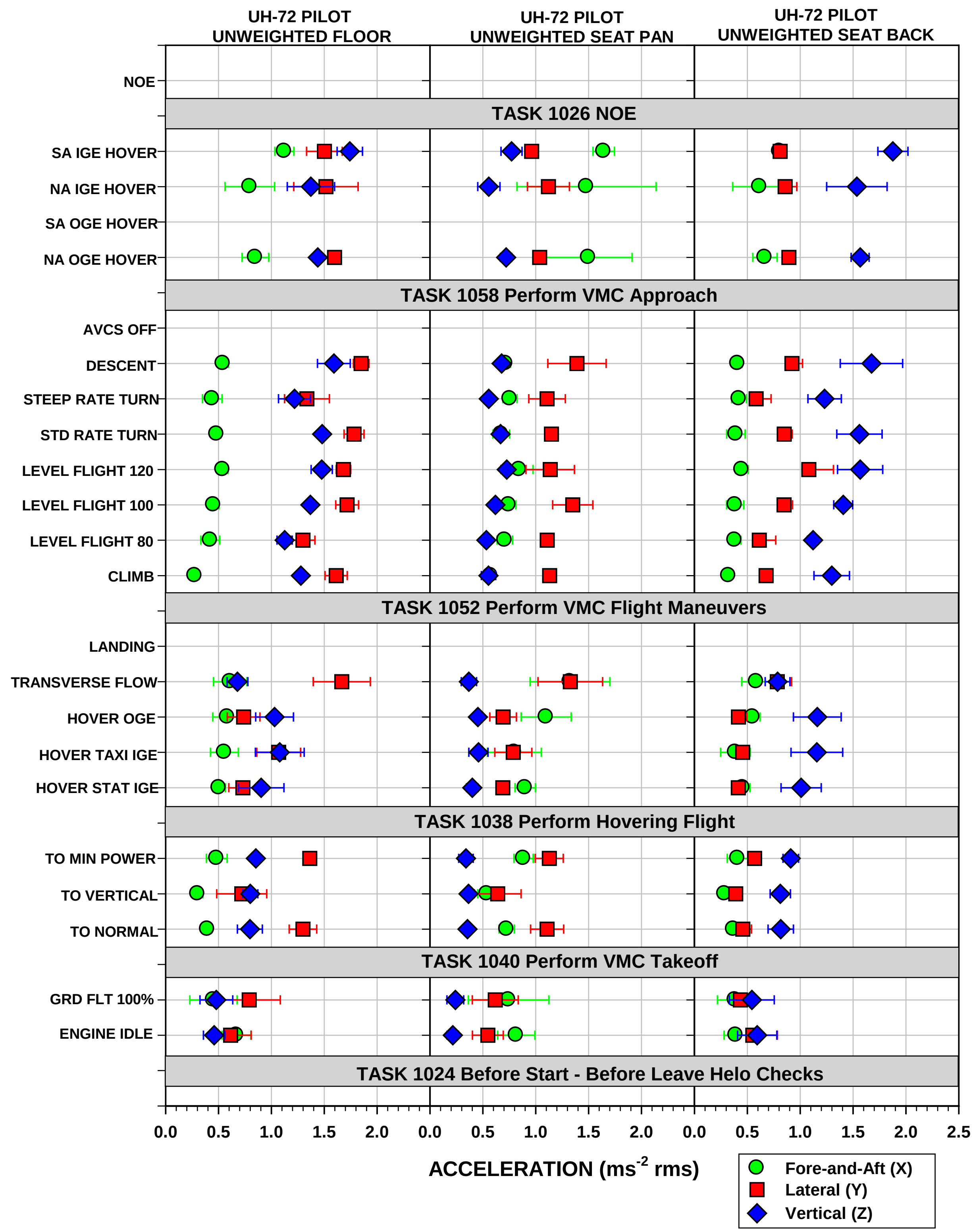

Figure A-7. UH-72 Mean Overall Unweighted Accelerations ± One Standard Deviation at the Pilot Station

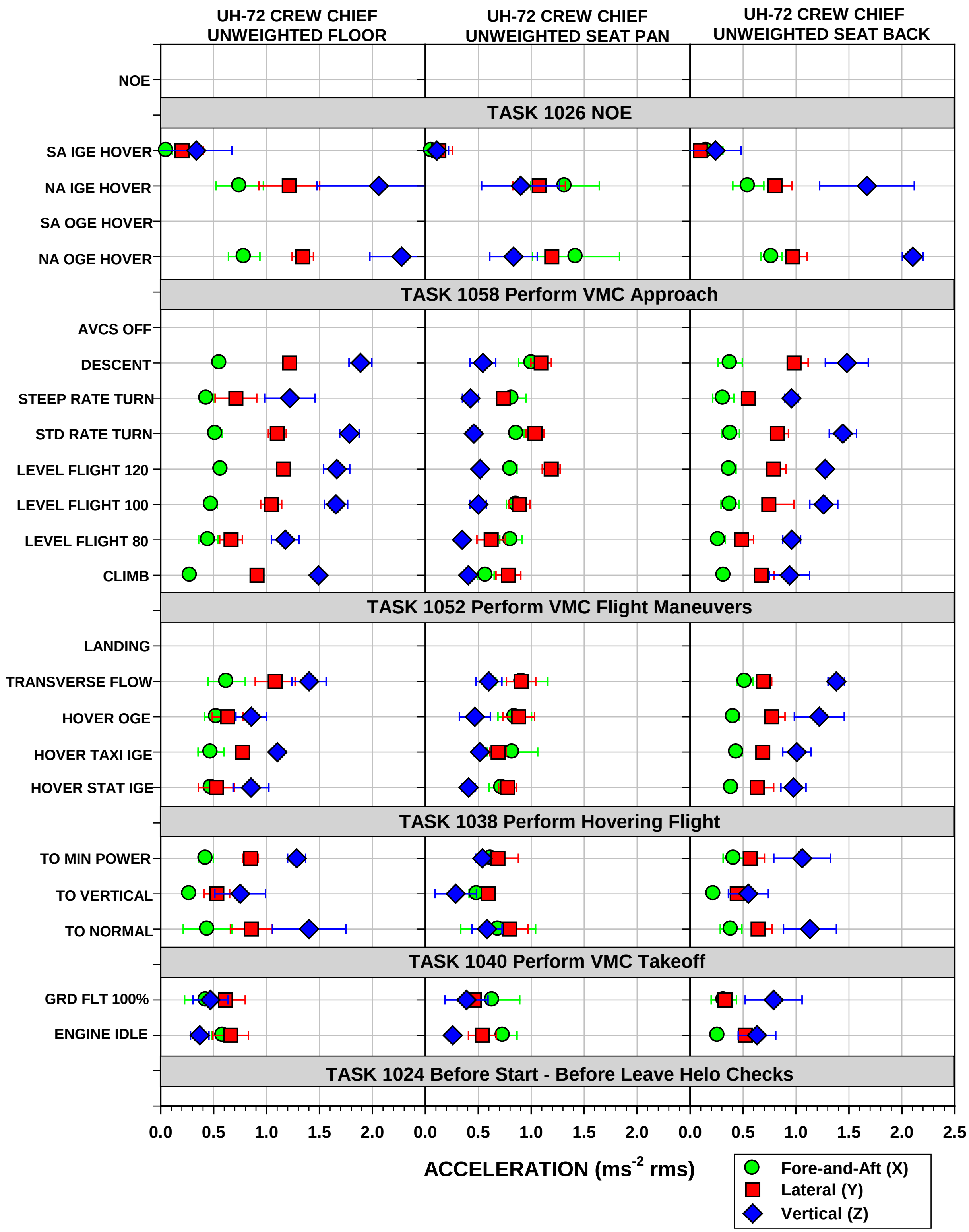

Figure A-8. UH-72 Mean Overall Unweighted Accelerations ± One Standard Deviation at the Crew Chief Station

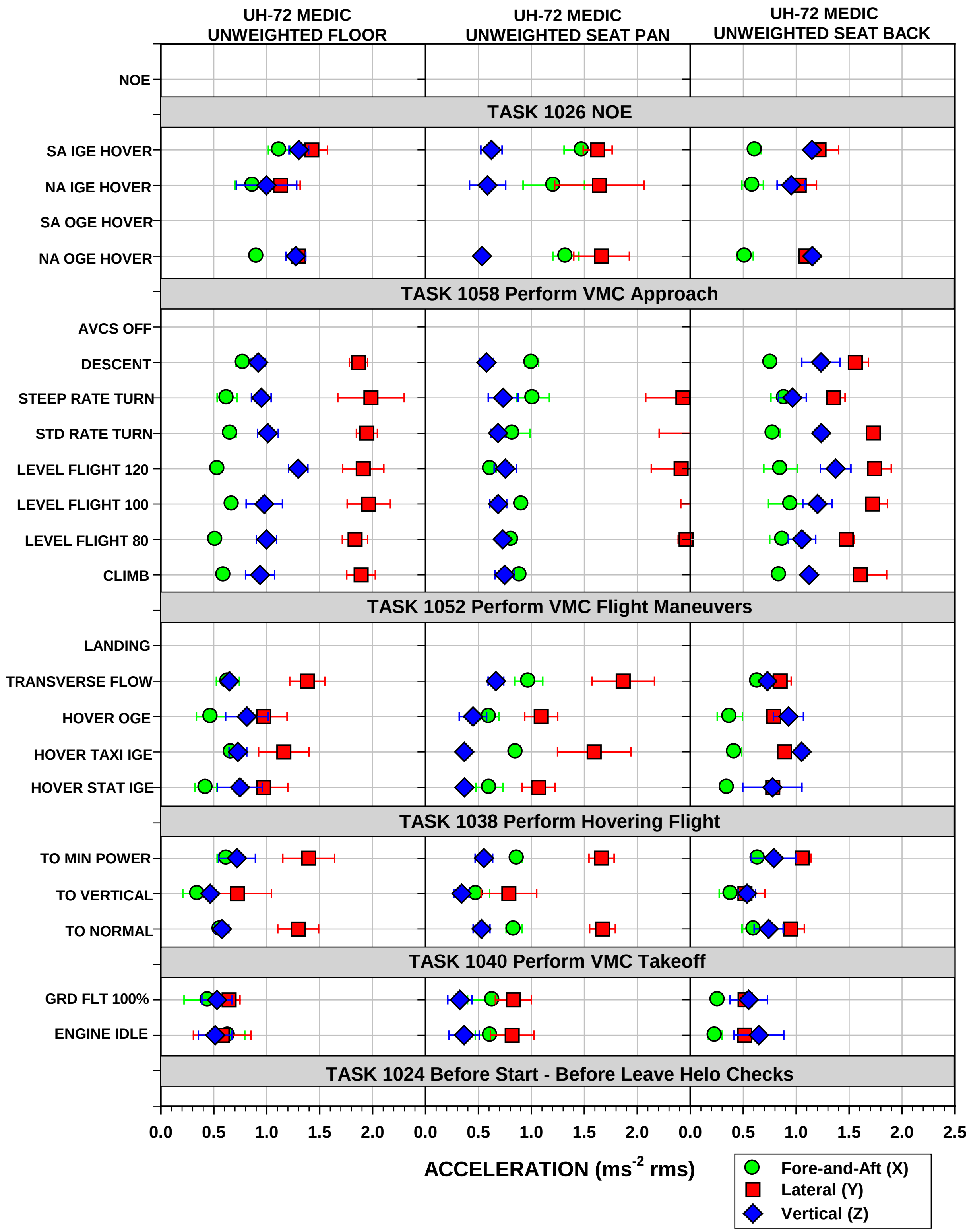

Figure A-9. UH-72 Mean Overall Unweighted Accelerations ± One Standard Deviation at the Medic Station

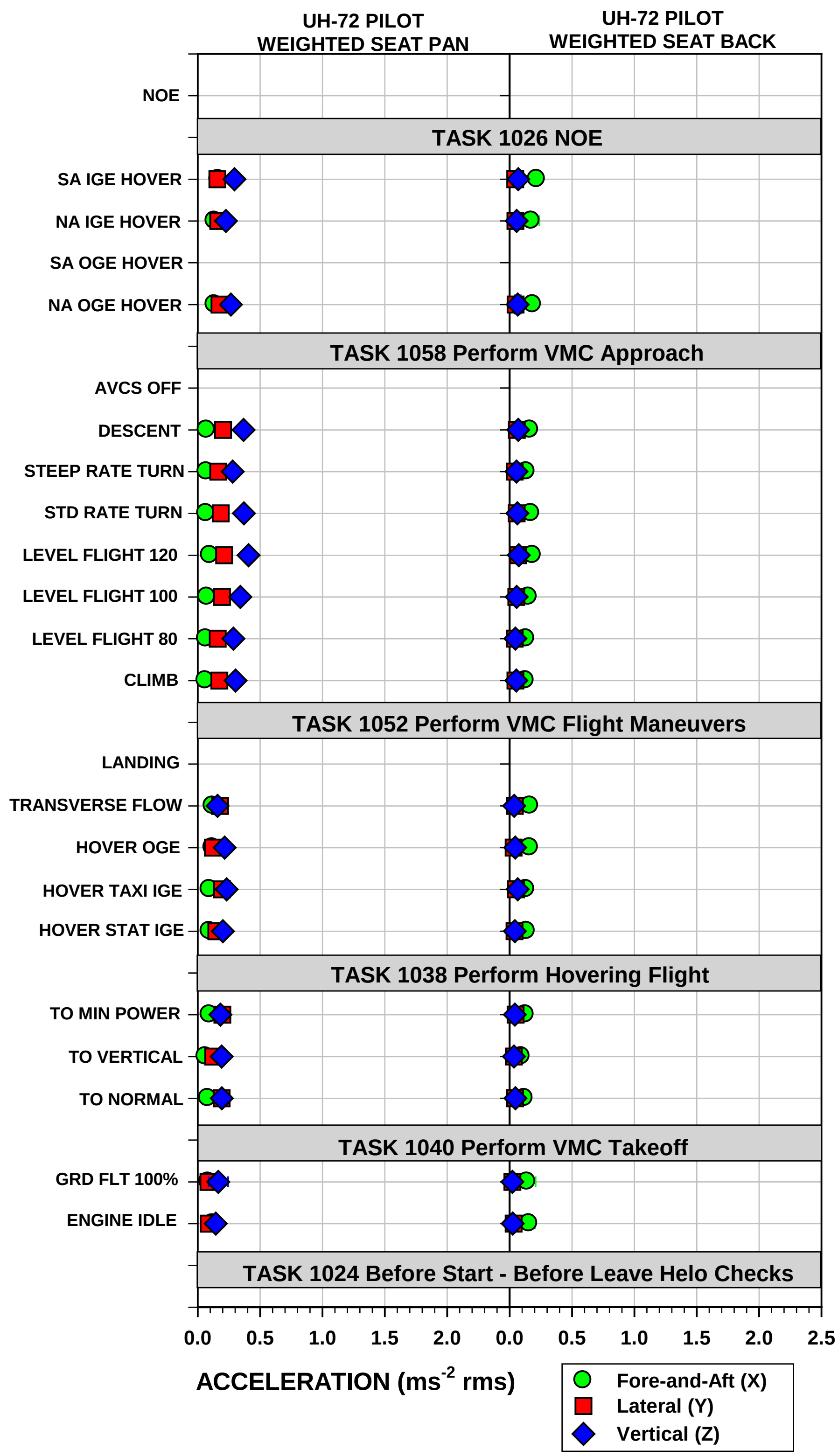

Figure A-10. UH-72 Mean Overall Weighted Accelerations ± One Standard Deviation at the Pilot Station

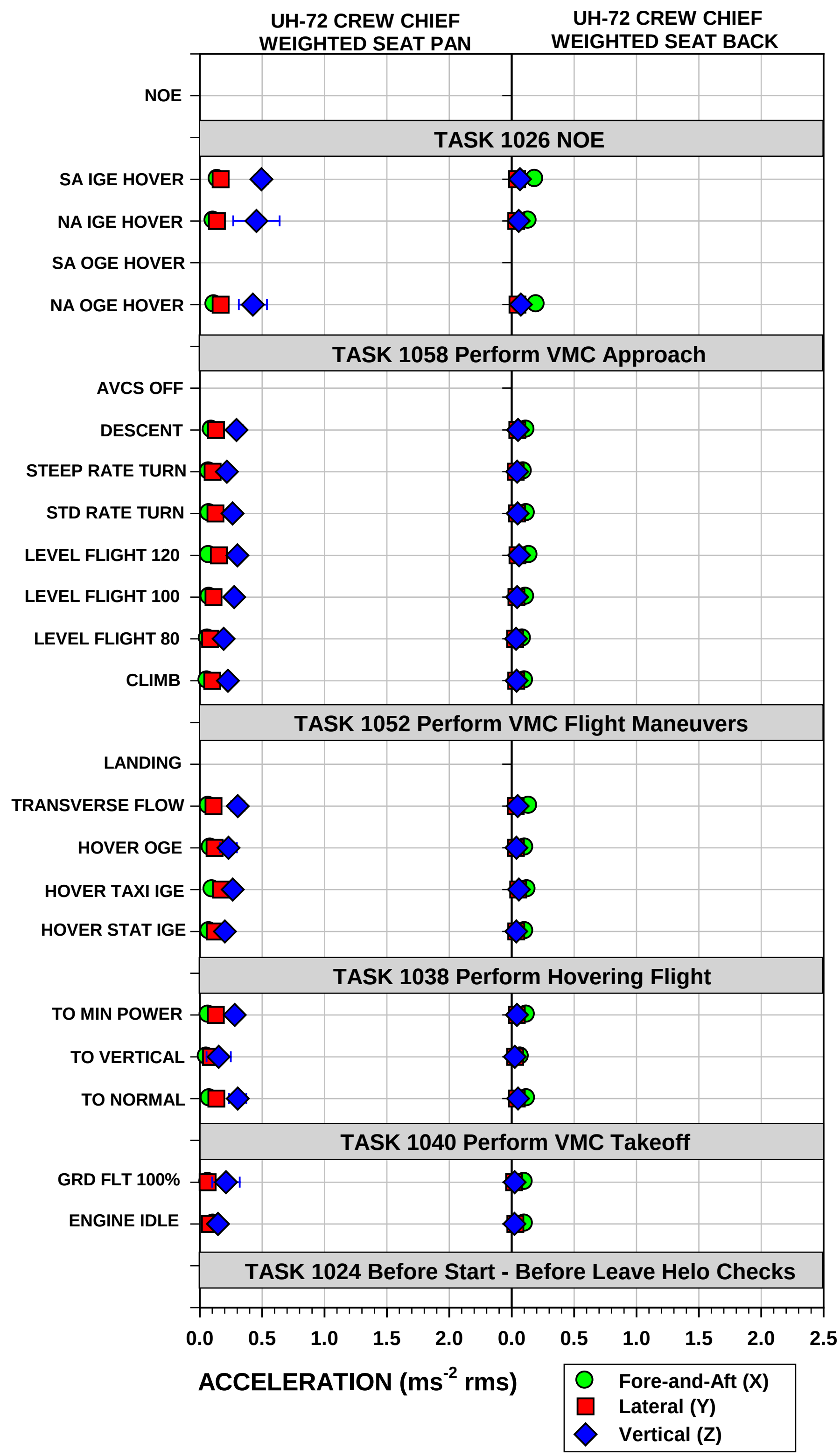

Figure A-11. UH-72 Mean Overall Weighted Accelerations ± One Standard Deviation at the Crew Chief Station

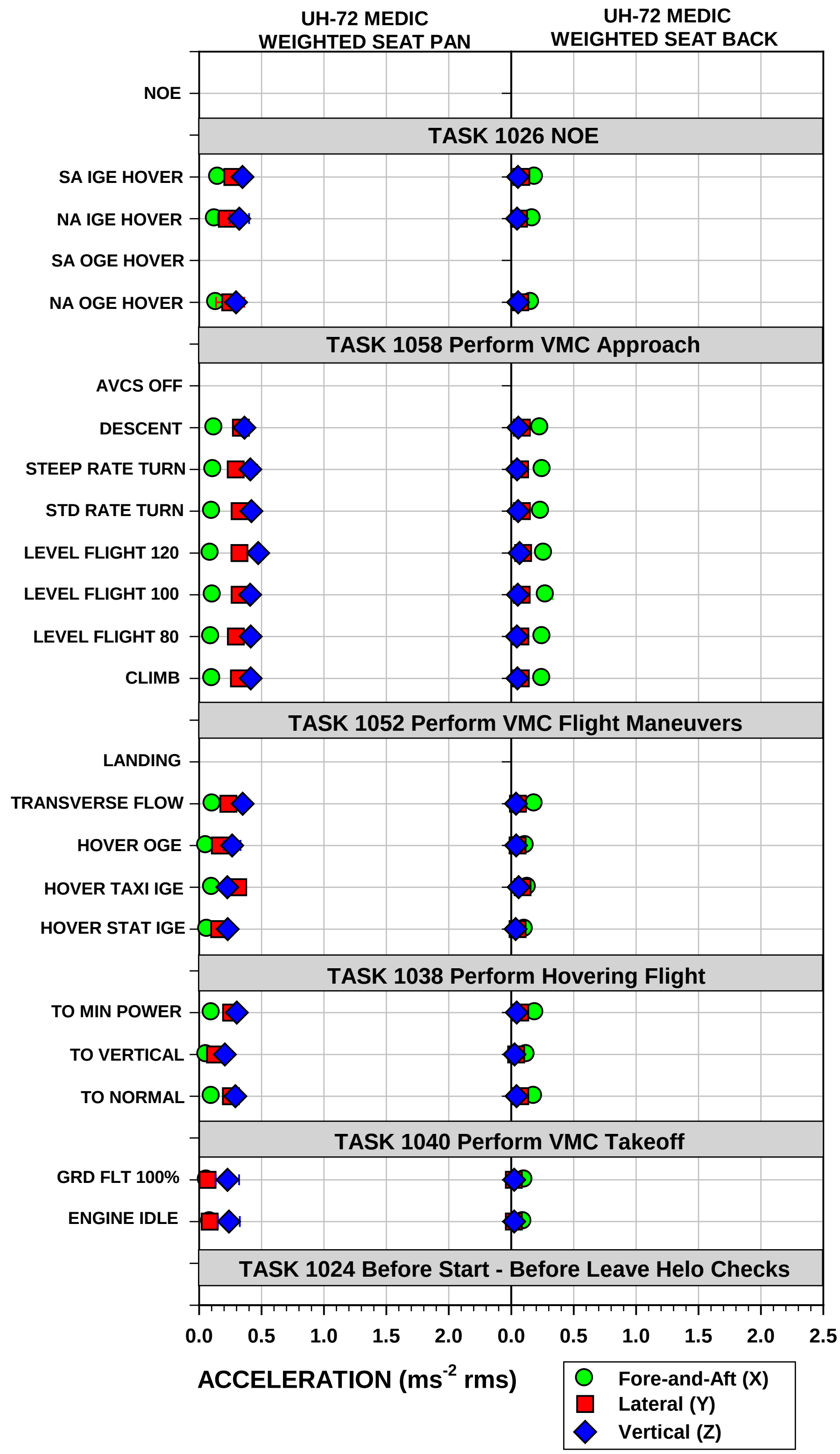

Figure A-12. UH-72 Mean Overall Weighted Accelerations ± One Standard Deviation at the Medic Station

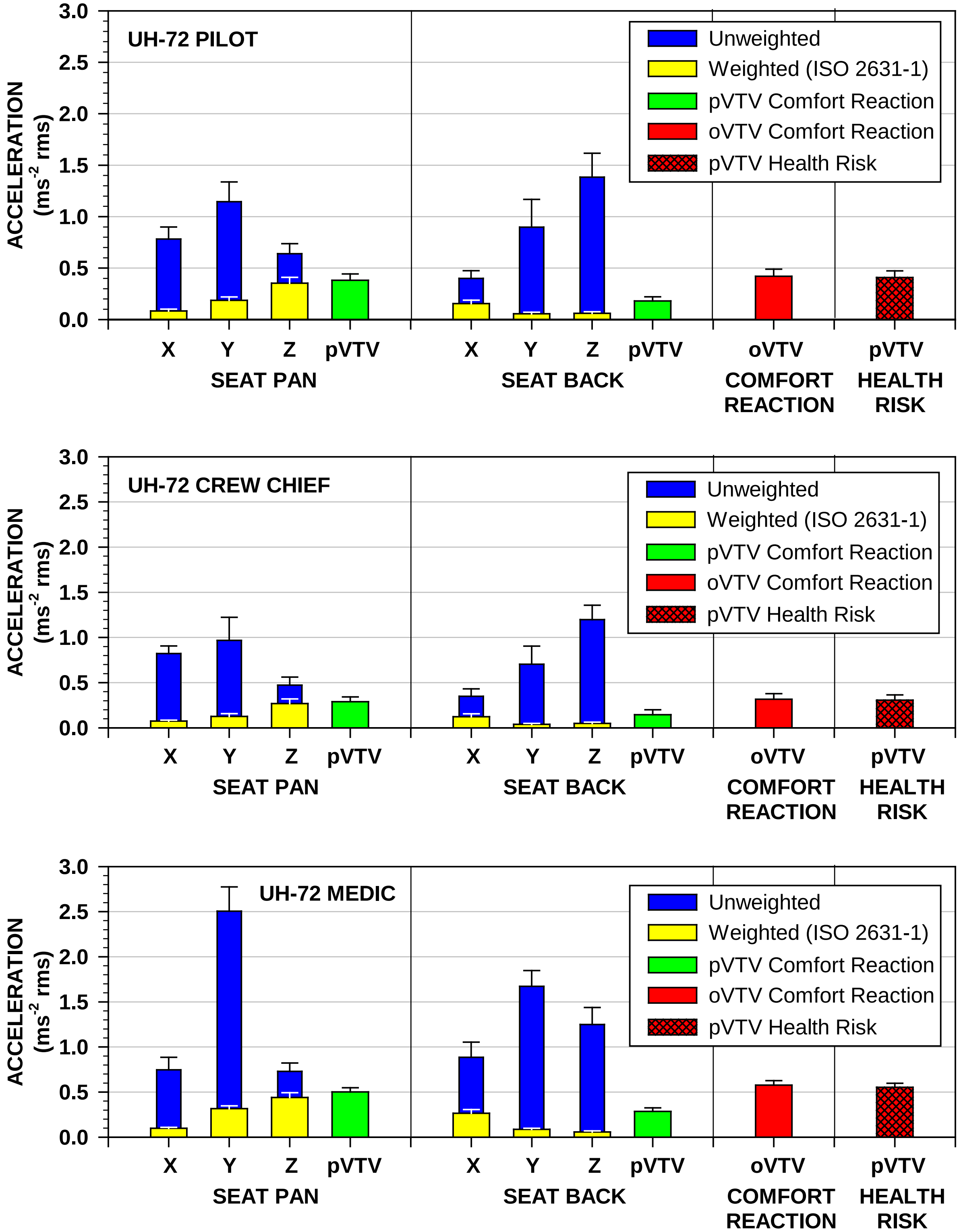

Figure A-13. UH-72 Mean Overall Unweighted and Weighted Accelerations, *pVTVs*, and *oVTVs* + One Standard Deviation for Level Flight

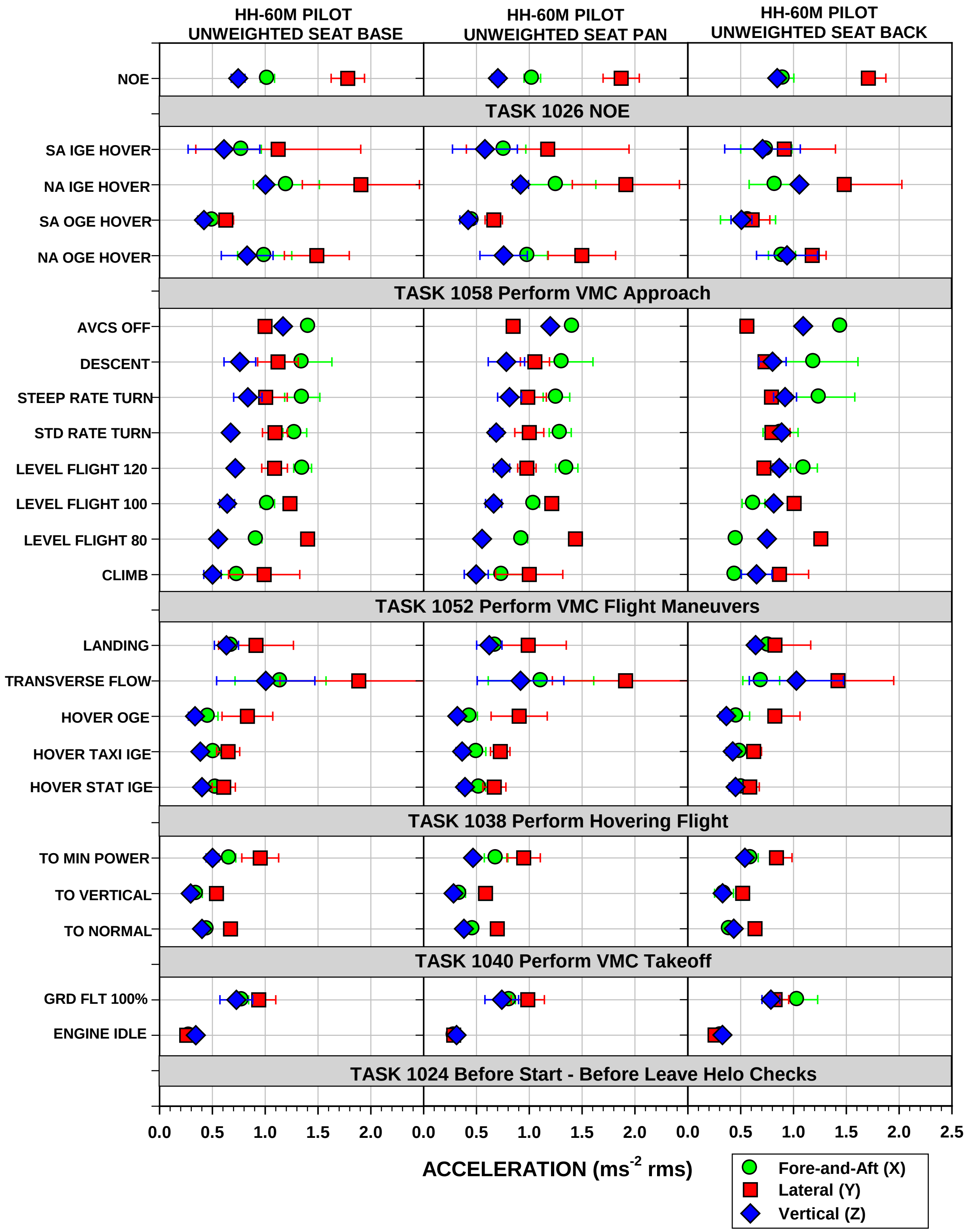

Figure A-14. HH-60M Mean Overall Unweighted Accelerations ± One Standard Deviation at the Pilot Station

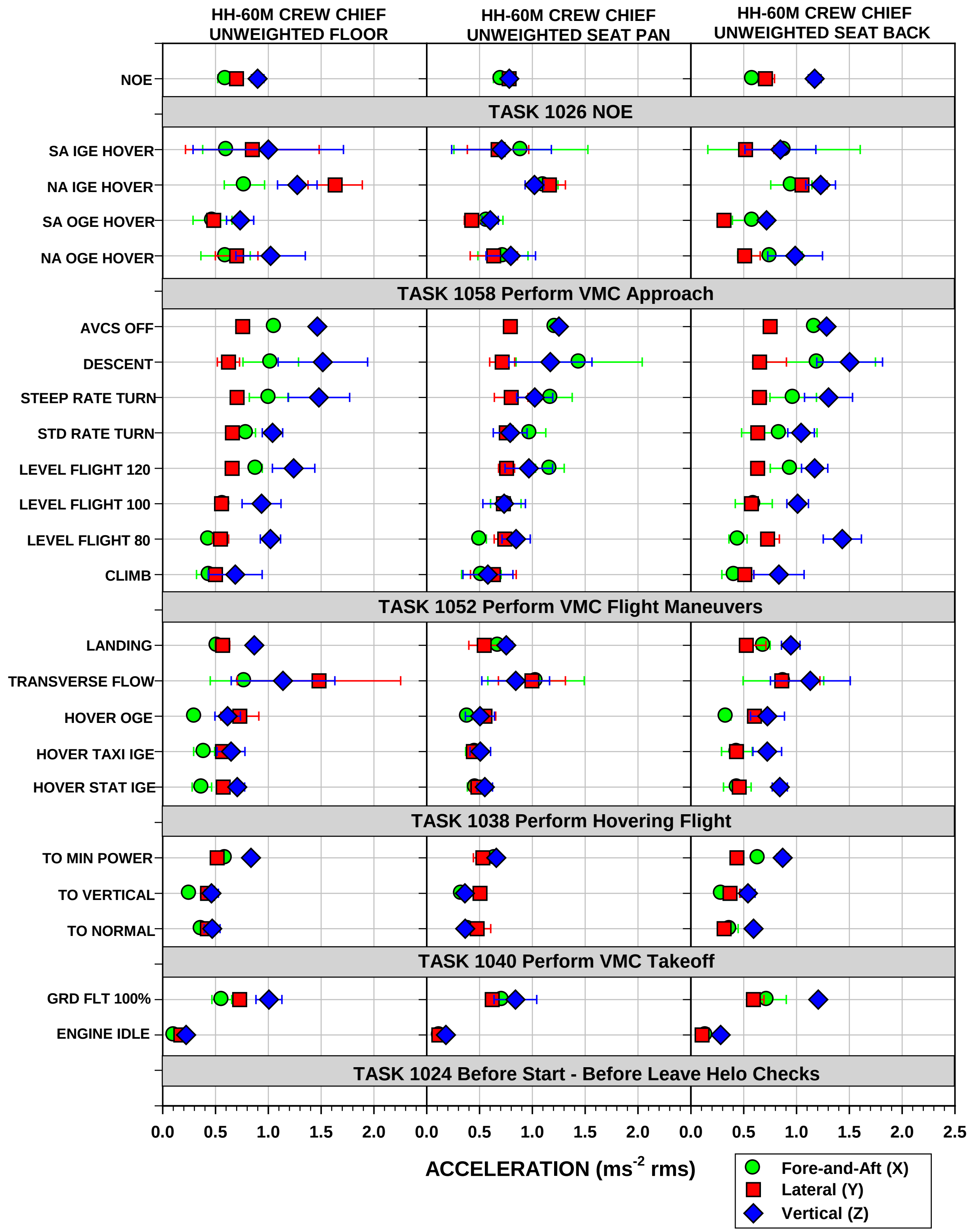

Figure A-15. HH-60M Mean Overall Unweighted Accelerations ± One Standard Deviation at the Crew Chief Station

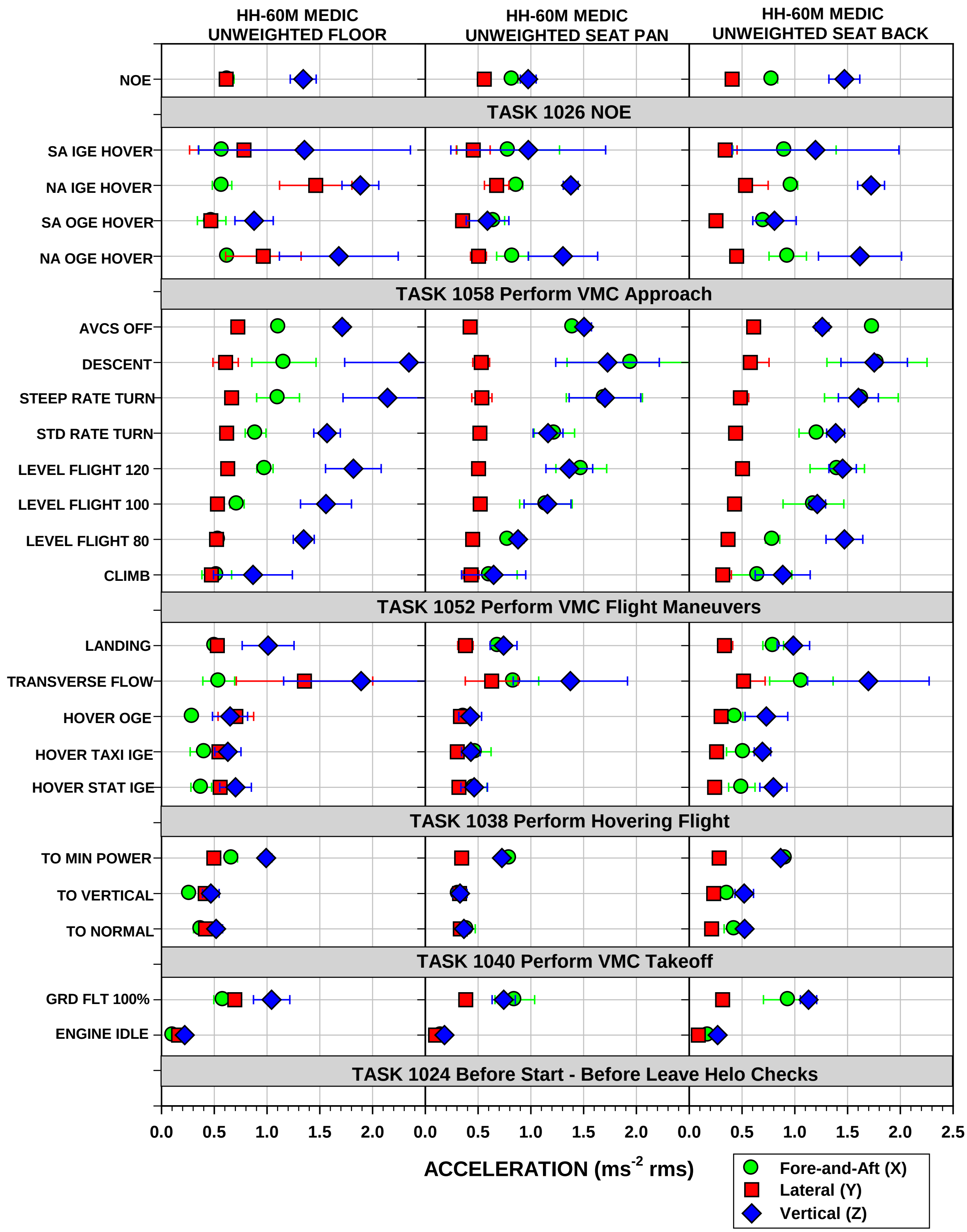

Figure A-16. HH-60M Mean Overall Unweighted Accelerations ± One Standard Deviation at the Medic Station

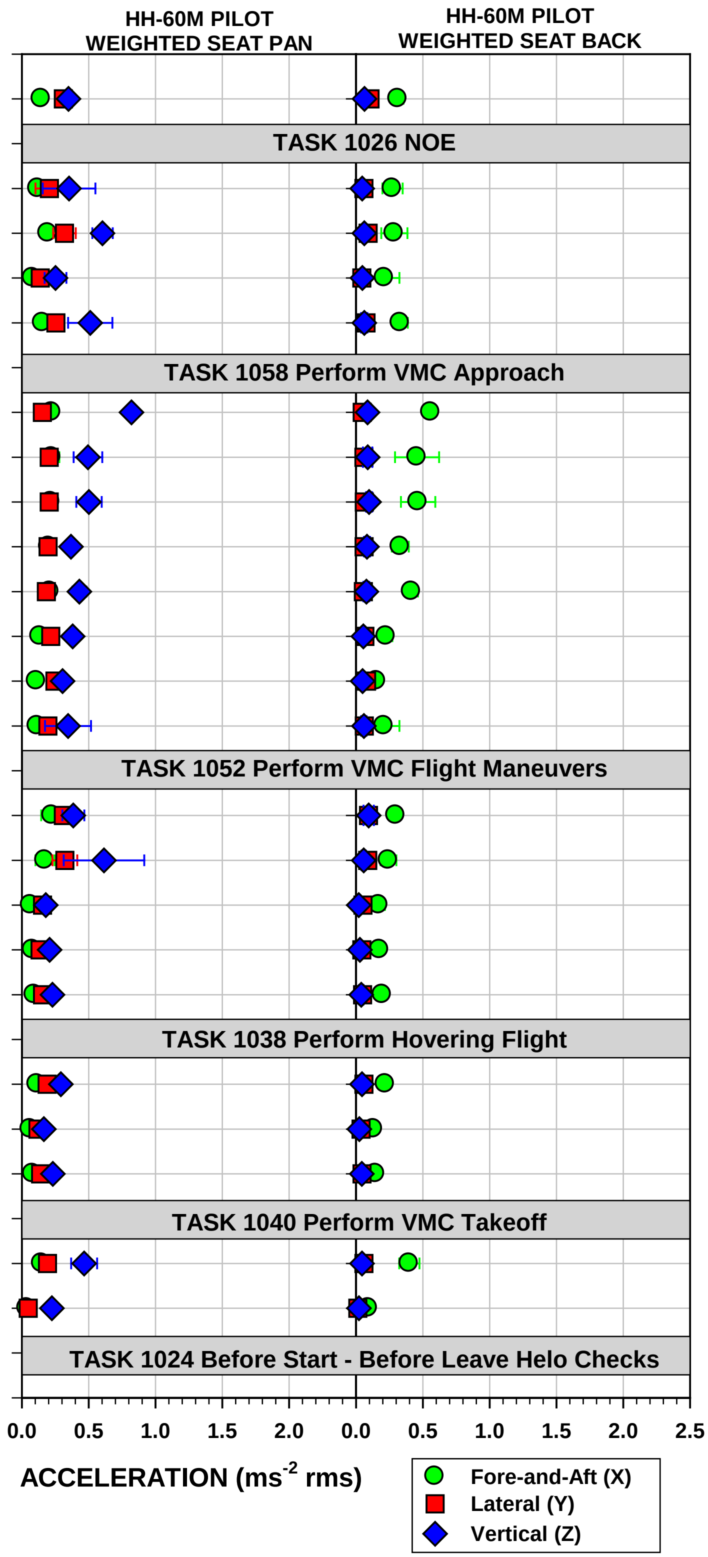

Figure A-17. HH-60M Mean Overall Weighted Accelerations ± One Standard Deviation at the Pilot Station

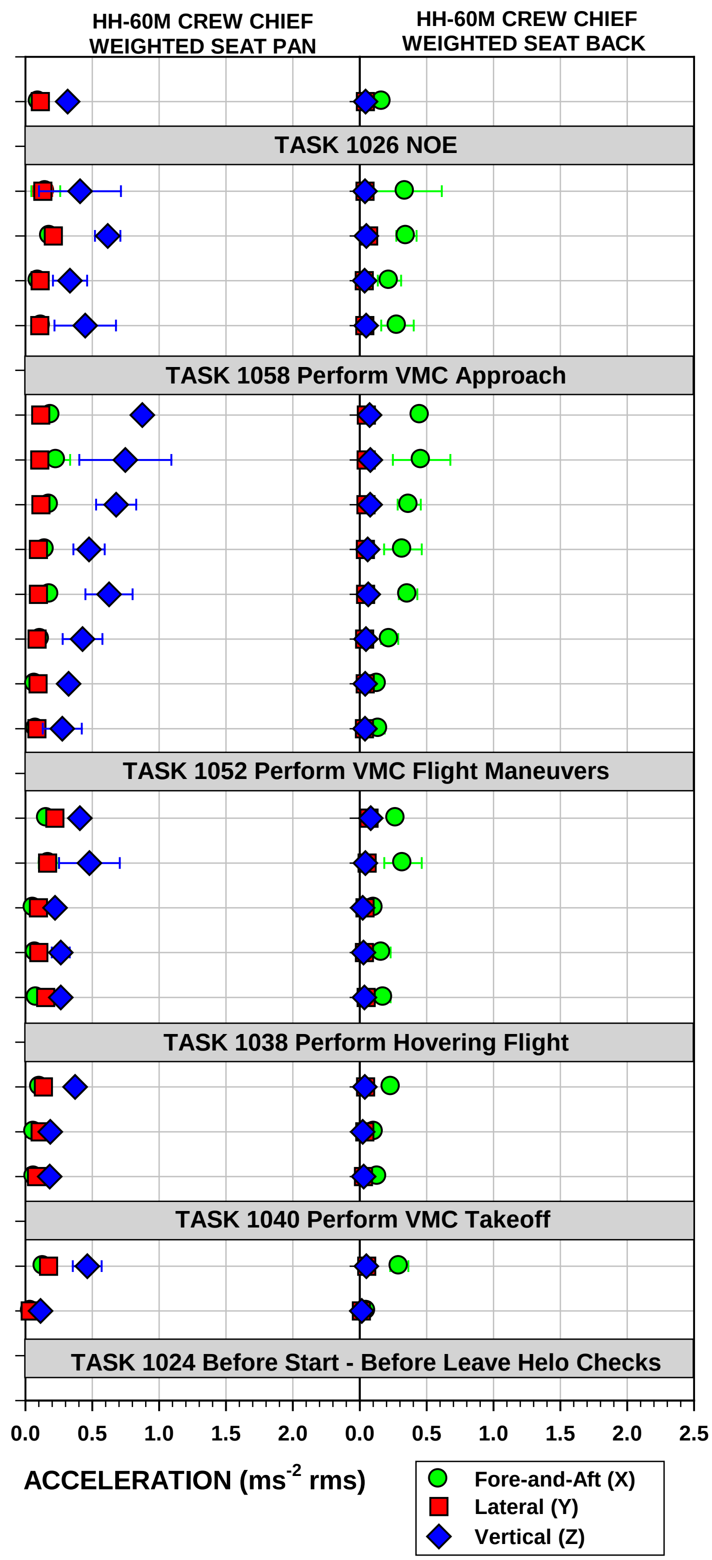

Figure A-18. HH-60M Mean Overall Weighted Accelerations ± One Standard Deviation at the Crew Chief Station

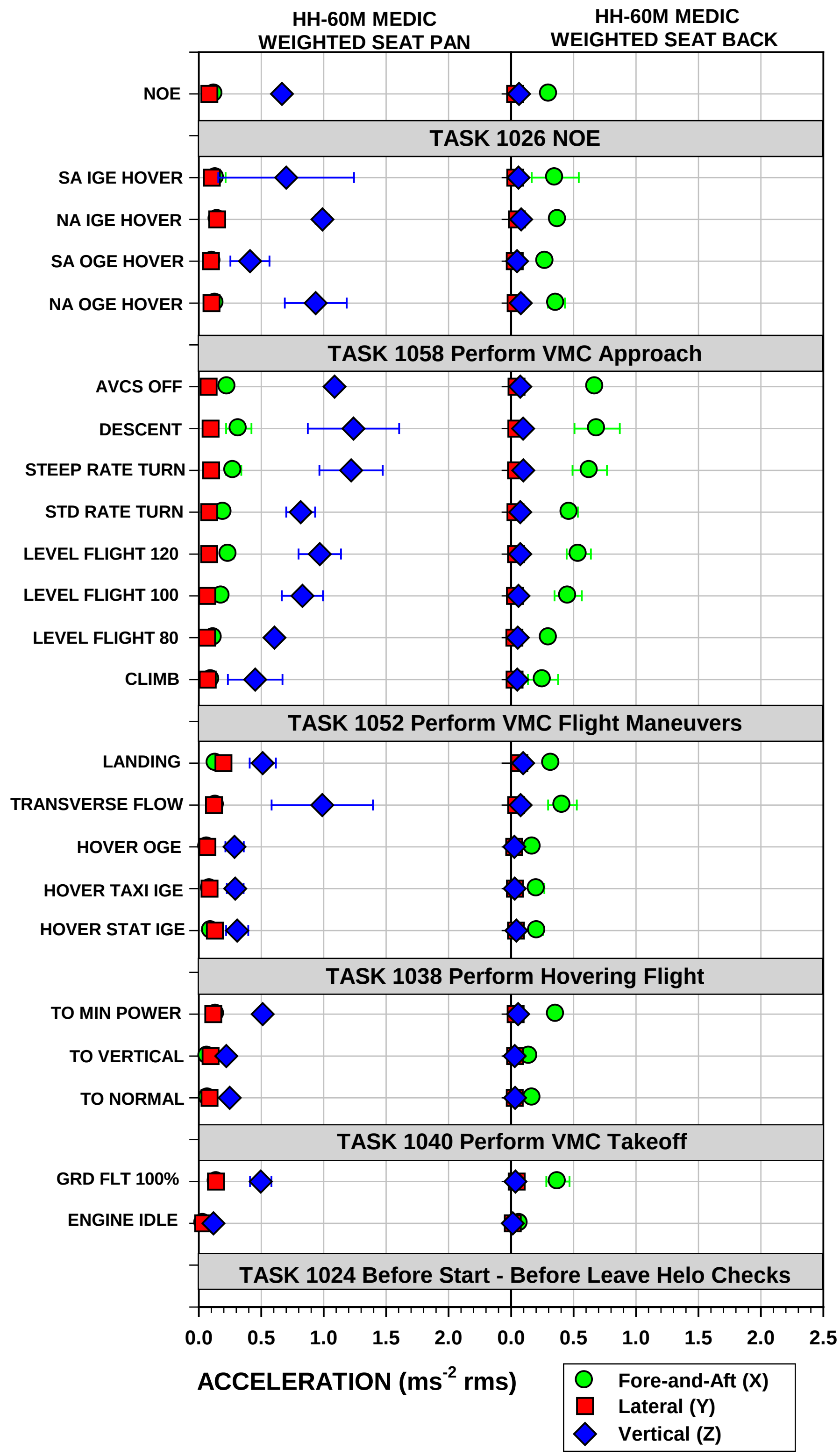

Figure A-19. HH-60M Mean Overall Weighted Accelerations ± One Standard Deviation at the Medic Station

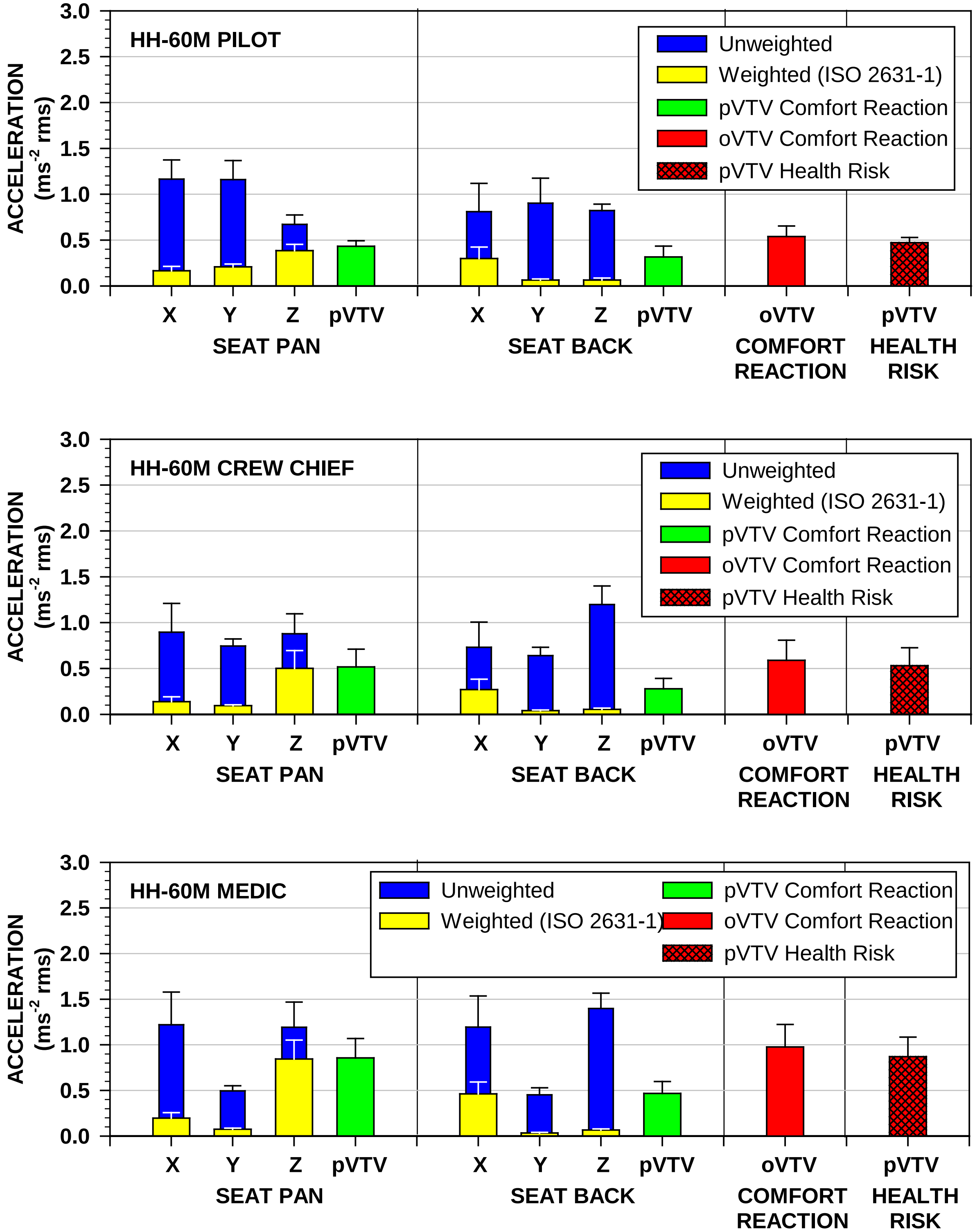

Figure A-20. HH-60M Mean Overall Unweighted and Weighted Accelerations, *pVTVs*, and *oVTVs* + One Standard Deviation for Level Flight

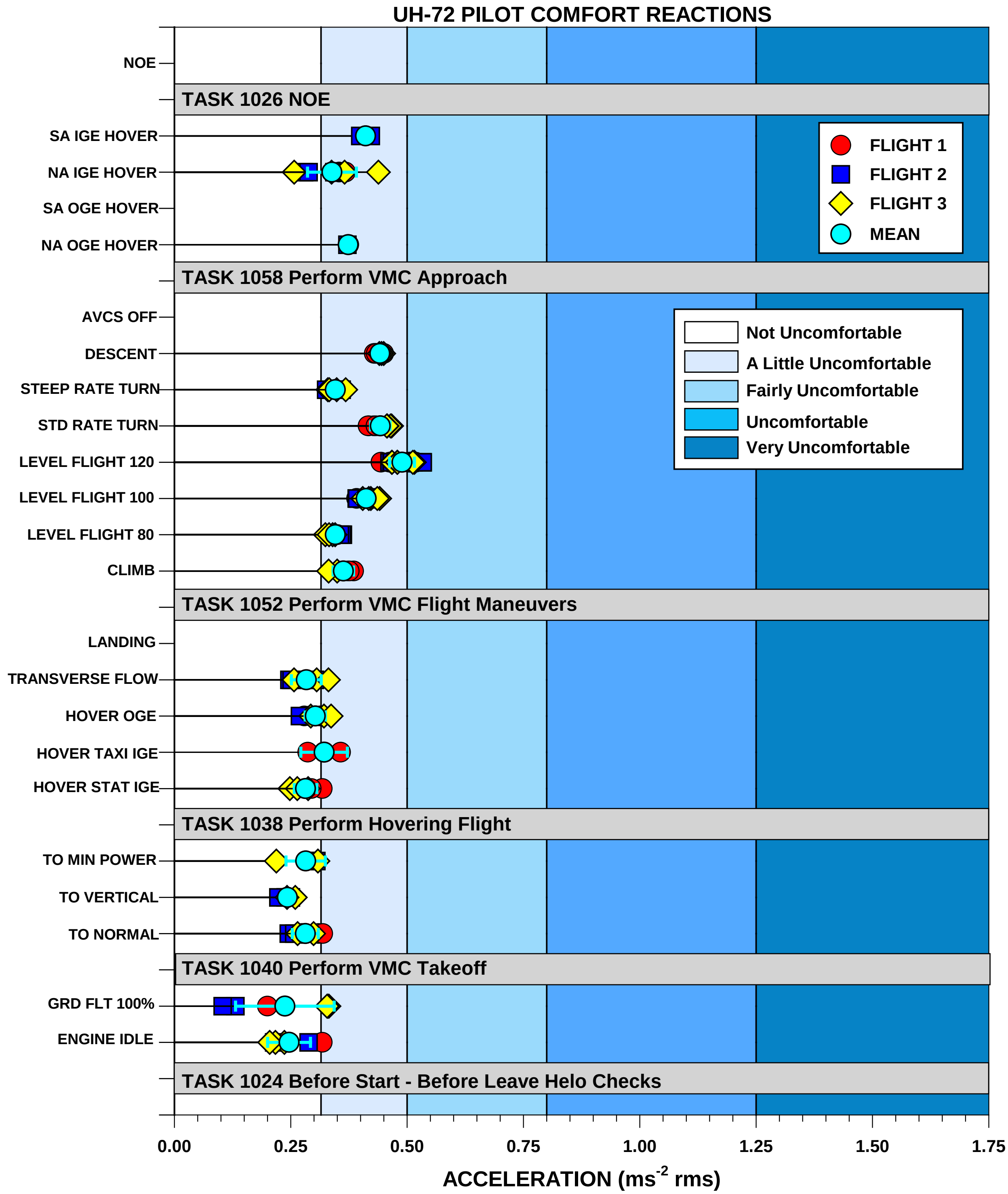

Figure A-21. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the UH-72 Pilot Station

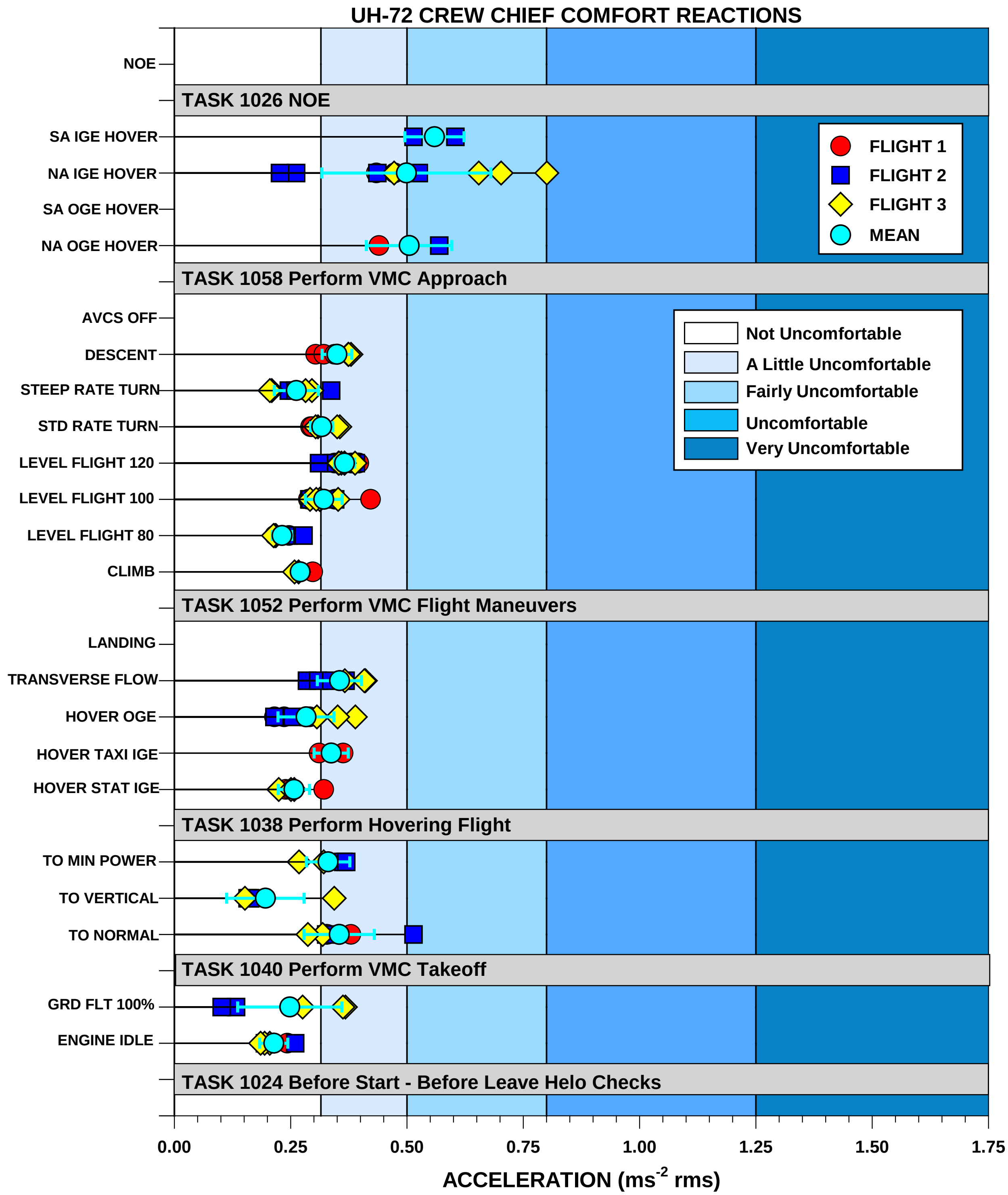

Figure A-22. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the UH-72 Crew Chief Station

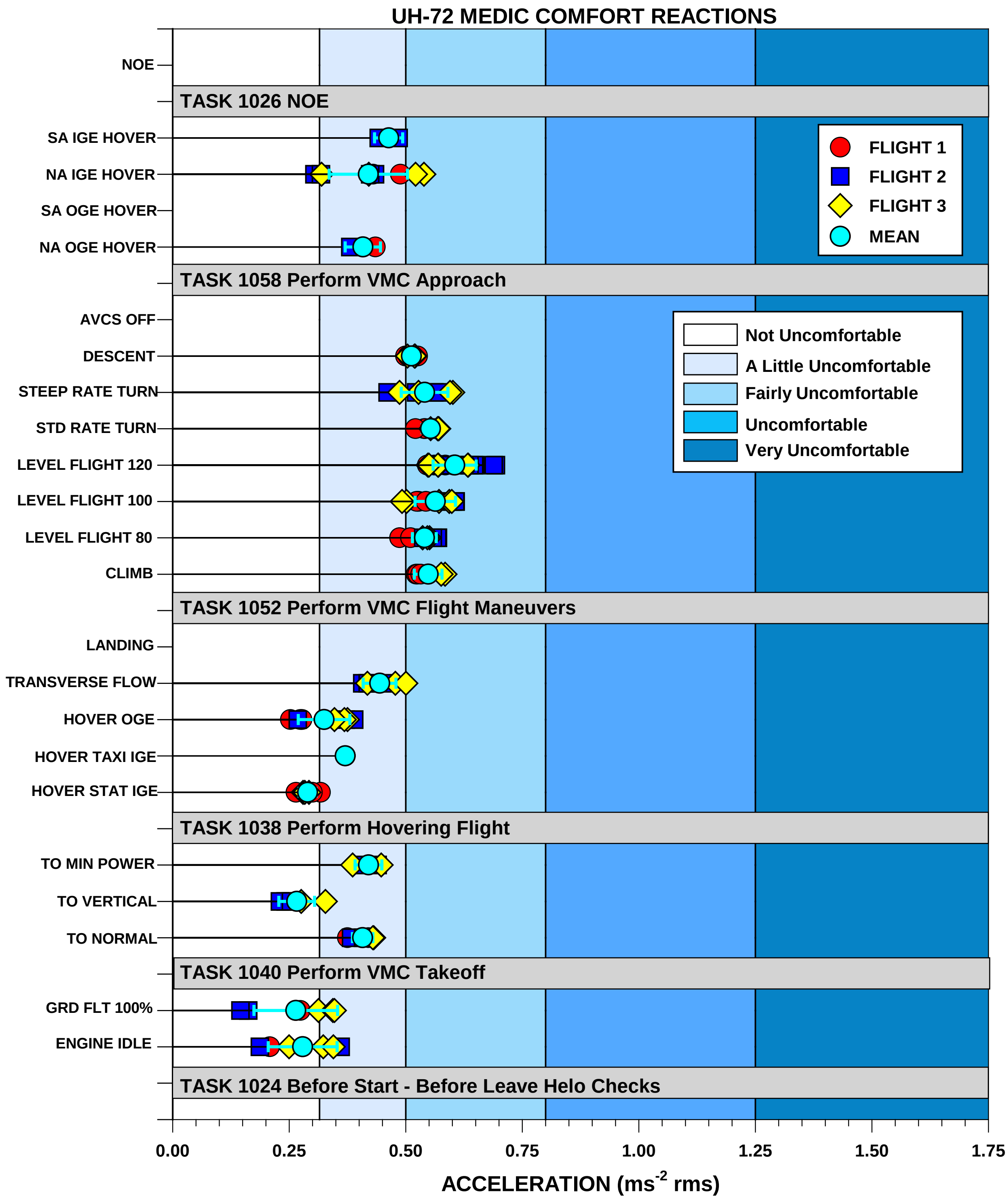

Figure A-23. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the UH-72 Medic Station

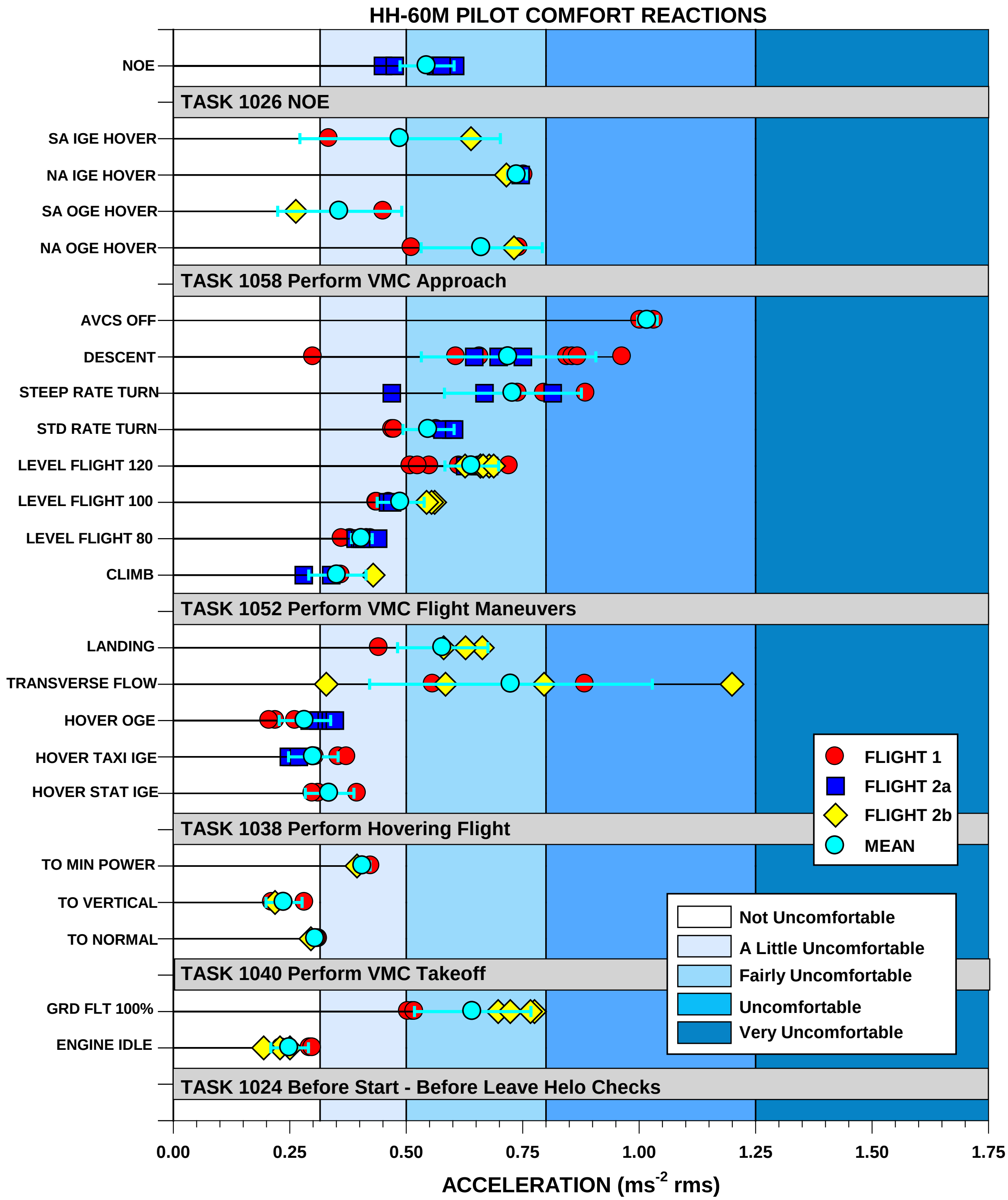

Figure A-24. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the HH-60M Pilot Station

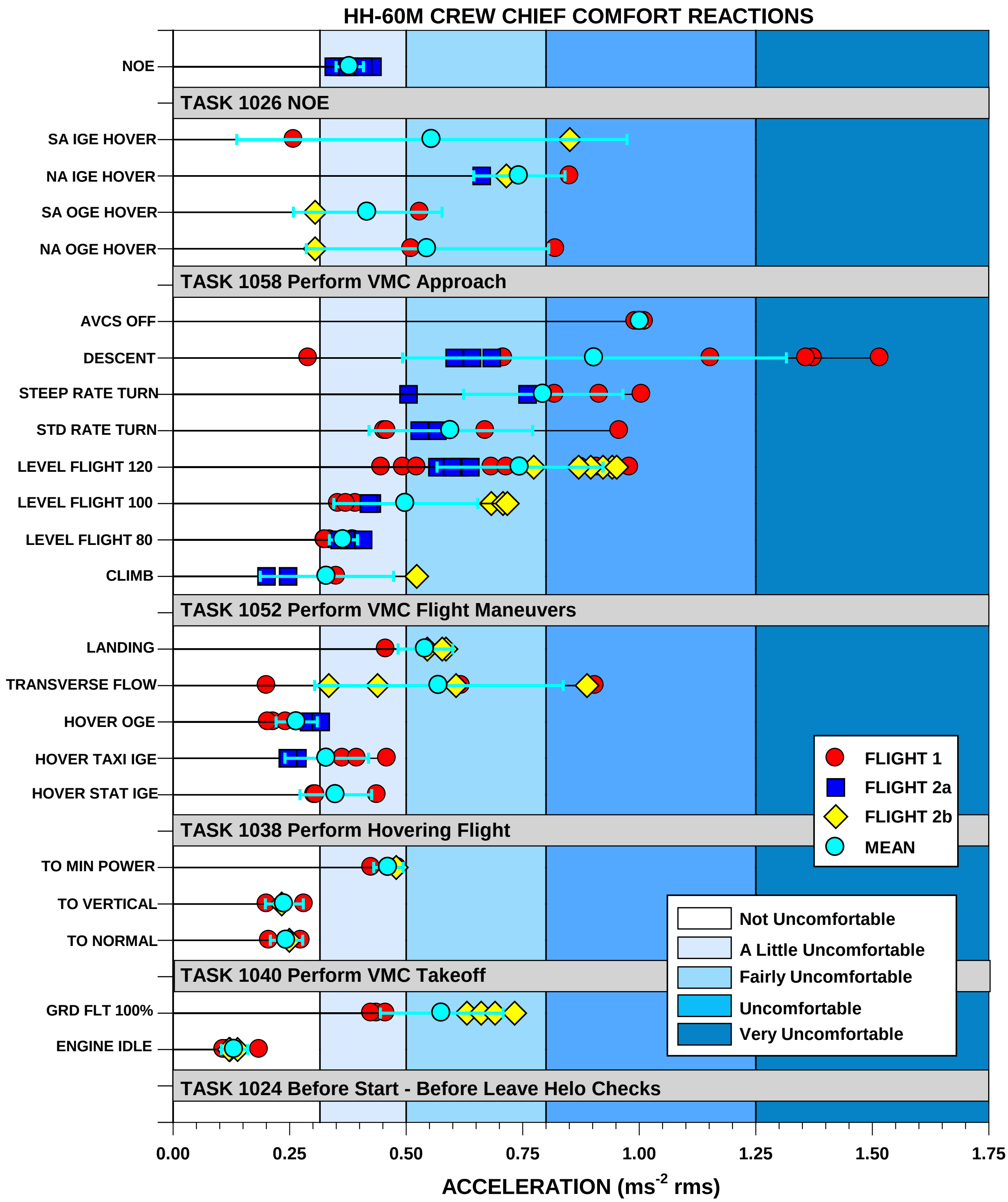

Figure A-25. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the HH-60M Crew Chief Station

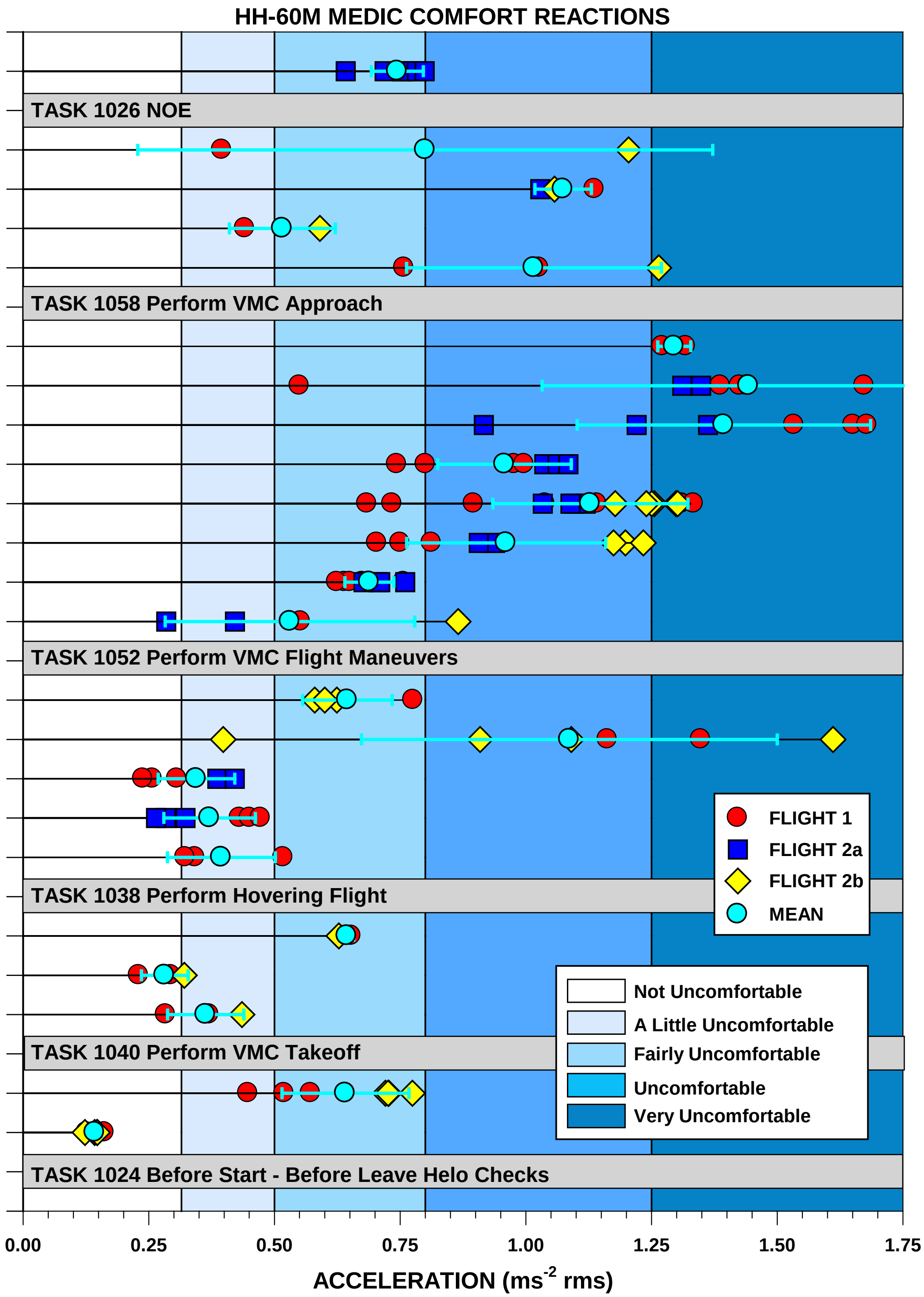

Figure A-26. ISO Comfort Reactions and *oVTVs* ± One Standard Deviation at the HH-60M Medic Station

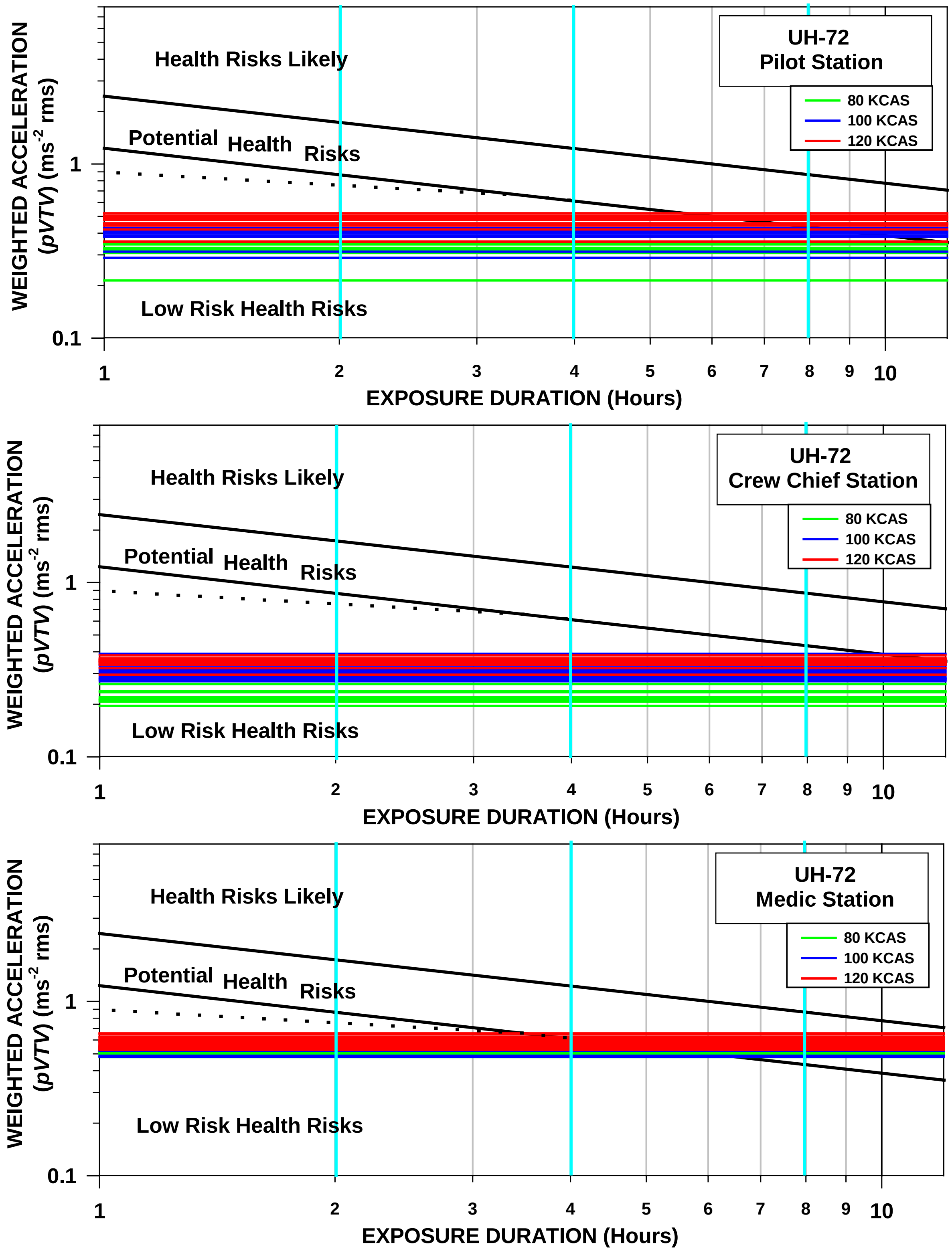

Figure A-27. ISO Health Guidance Caution Zones and UH-72 Seat Pan *pVTVs* for Level Flight

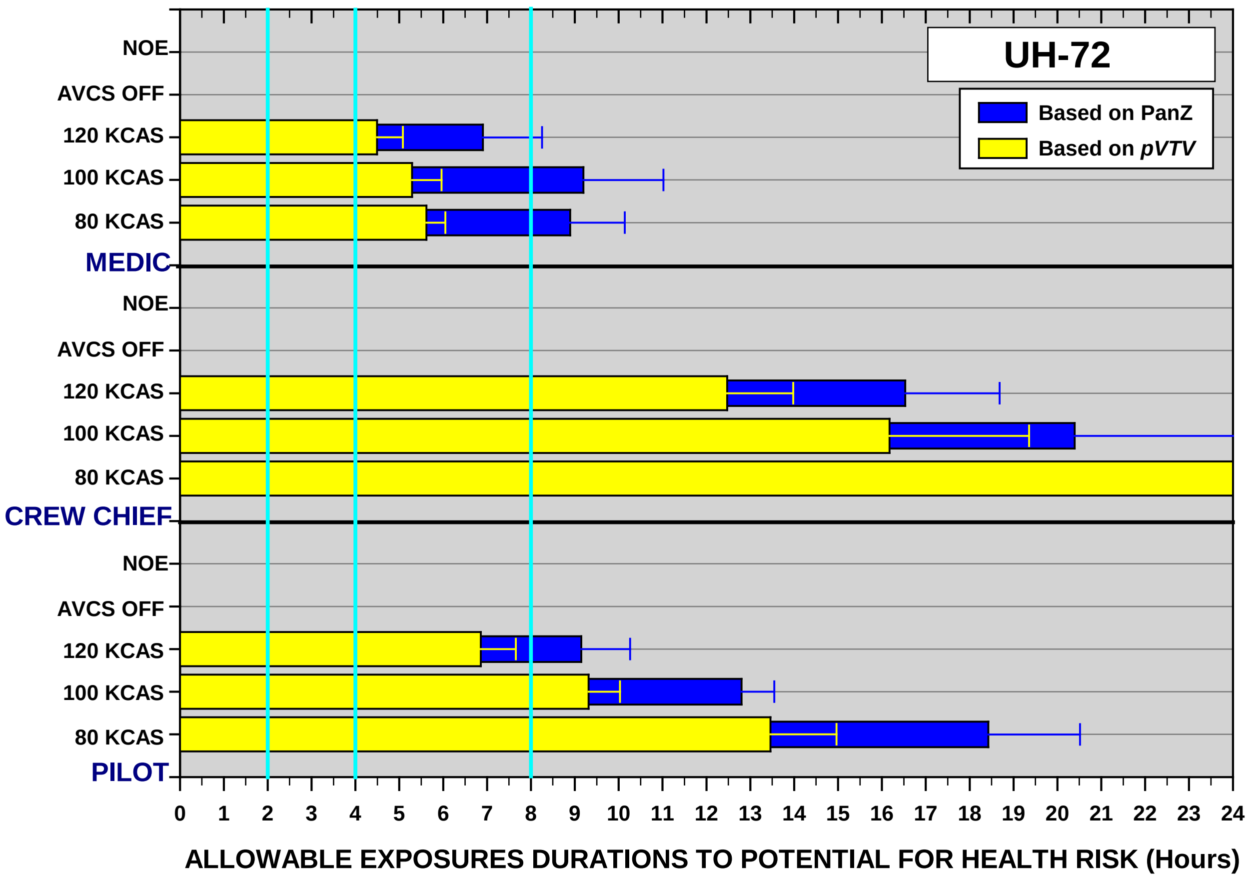

Figure A-28. UH-72 Mean Allowable Exposure Durations to Potential for Health Risk ± One Standard Deviation

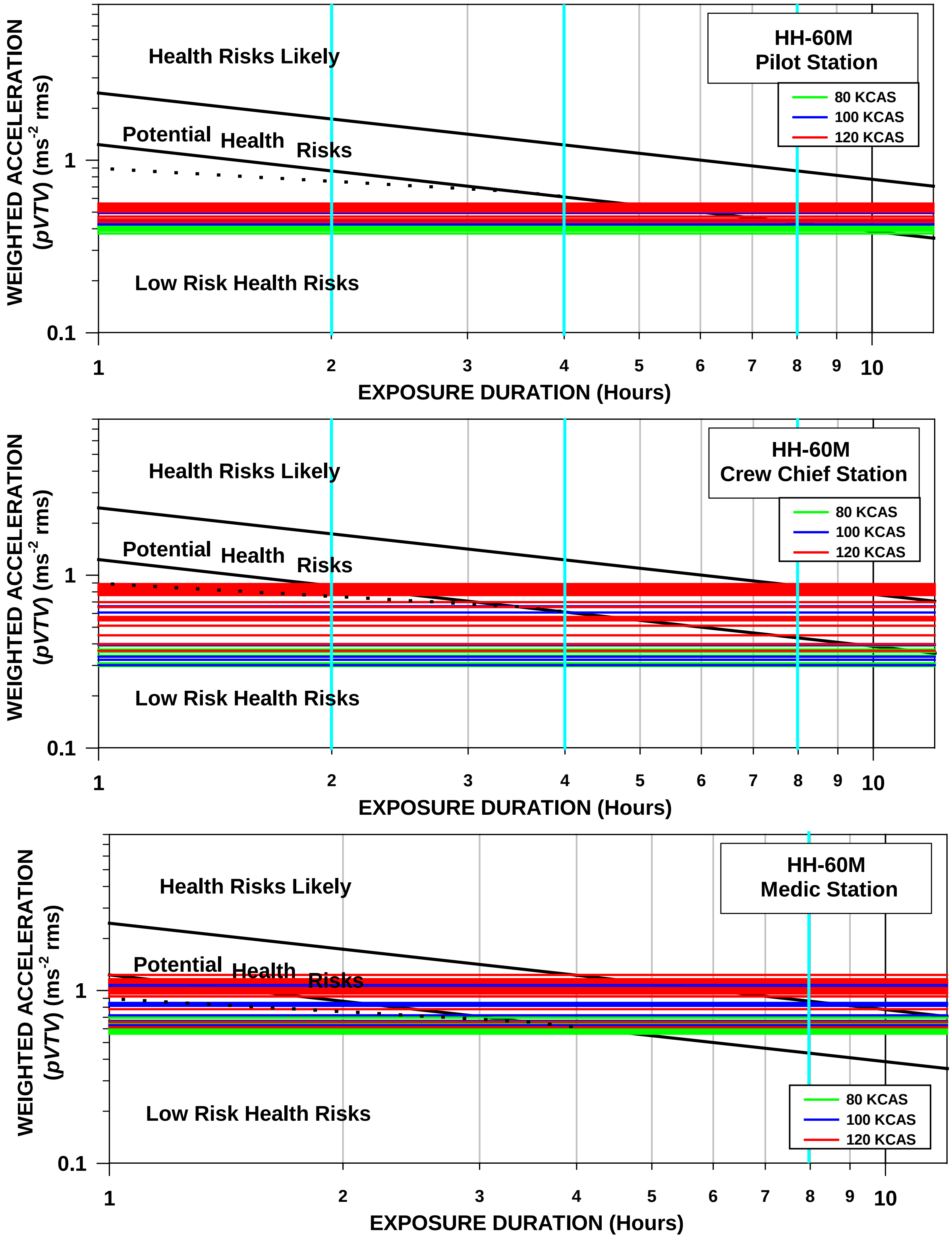

Figure A-29. ISO Health Guidance Caution Zones and HH-60M Seat Pan *pVTVs* for Level Flight

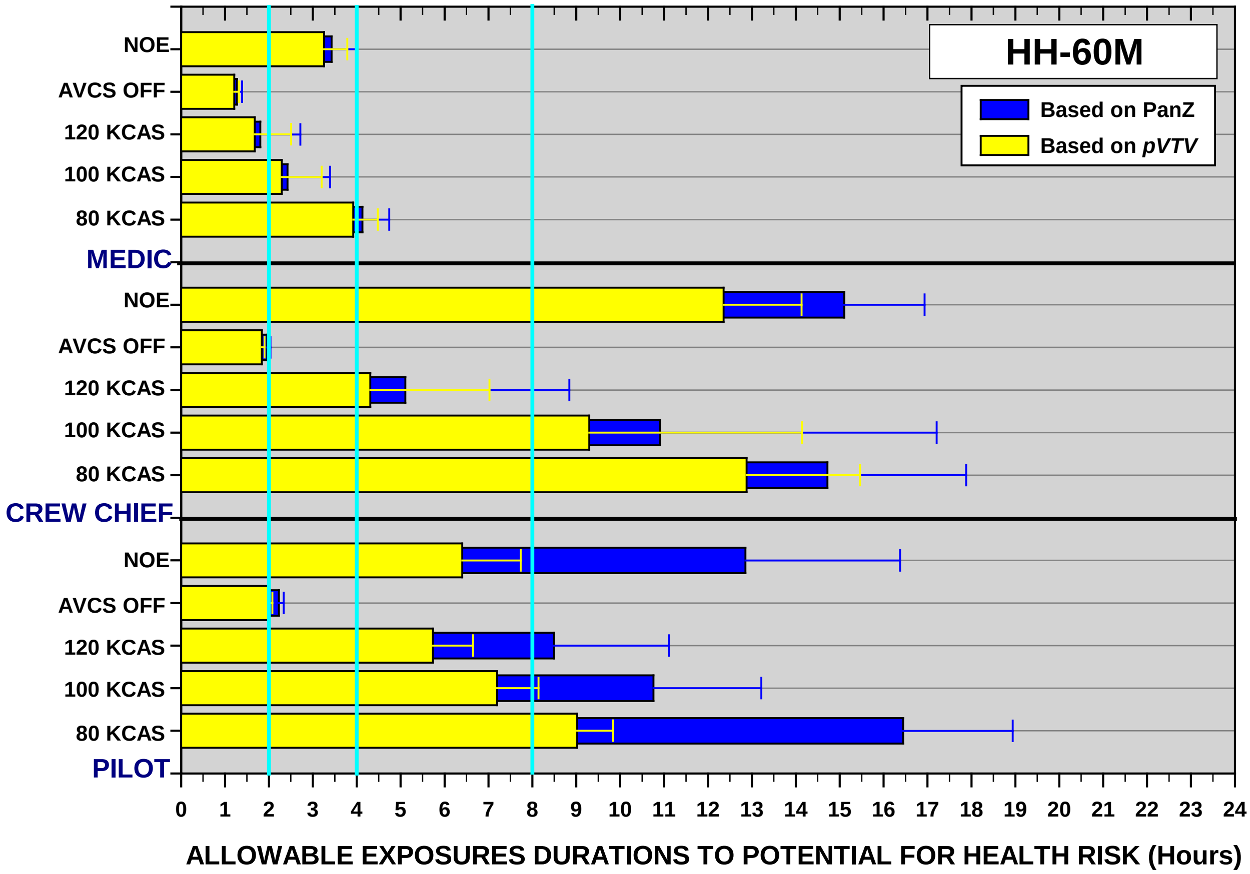

Figure A-30. HH-60M Mean Allowable Exposure Durations to Potential for Health Risk + On Standard Deviation

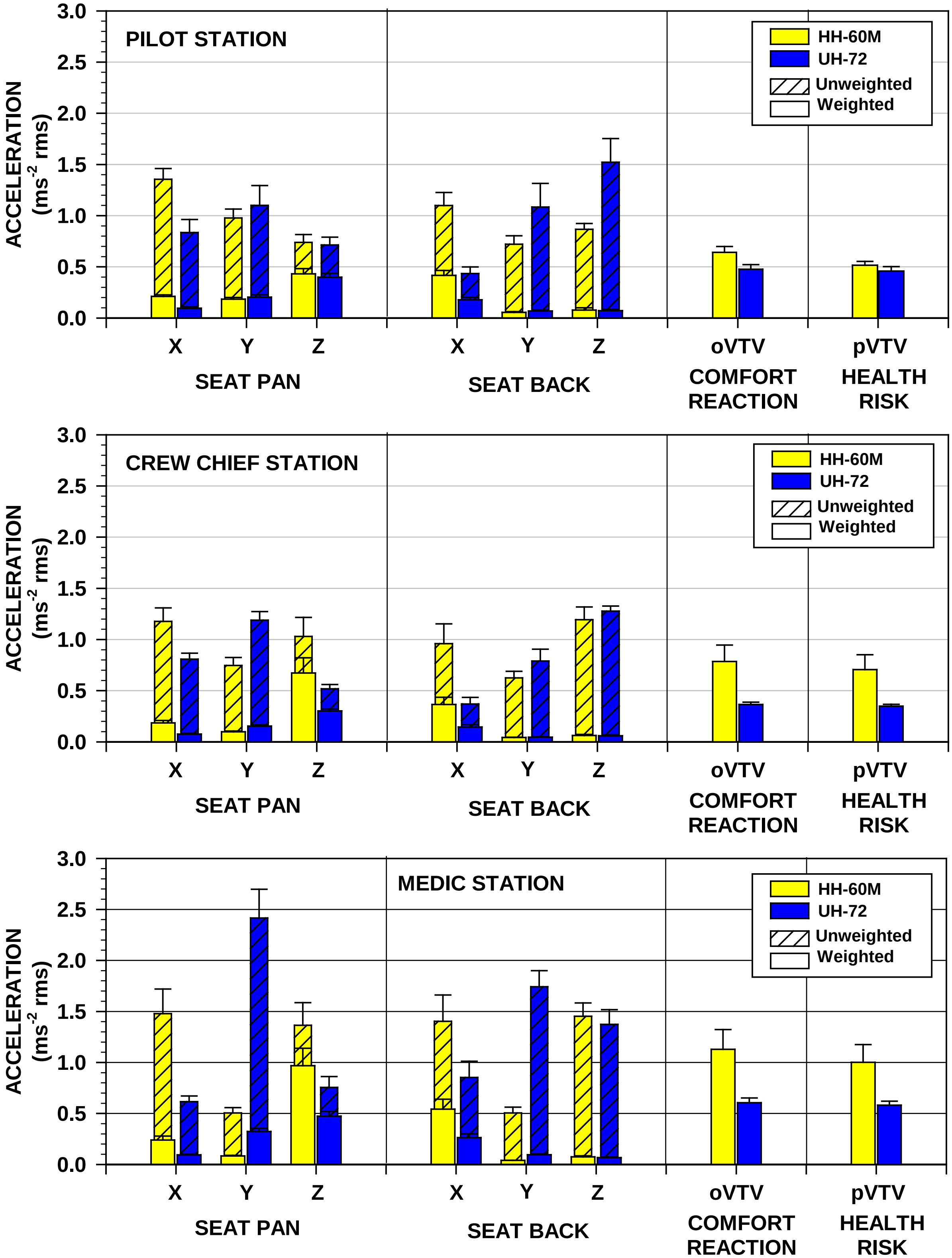

Figure A-31. UH-72 and HH-60M Mean Overall Unweighted and Weighted Seat Pan and Seat Back Accelerations, *oVTVs* and *pVTVs* + One Standard Deviation

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

a_{rms}	Root-Mean-Square Acceleration
a_{wrms}	Weighted Root-Mean-Square Acceleration
BPF	Blade Passage Frequency
AWR	Air Worthiness Release
DAU	Data Acquisition Unit
HGCZ	Health Guidance Caution Zones (ISO 2631-1, Annex B)
k	Multiplying Factor (ISO 2631-1)
oVTV	Overall Vibration Total Value
PRF	Propeller Rotation Frequency
pVTV	Point Vibration Total Value
REVER	Remote Vibration Environment Recorder
rms	Root-Mean-Square
W	Frequency Weighting (ISO 2631-1)